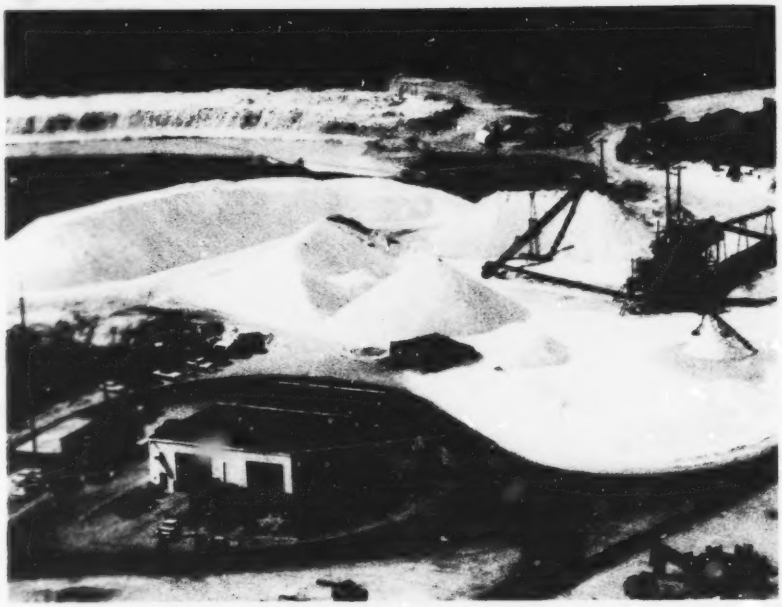

Cretaceous Deposits of Nova Scotia

by G.B. Dickie

Nova Scotia

Department of Mines and Energy

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Cover photo: Nova Scotia Sand and Gravel silica sand plant, Shubenacadie, Nova Scotia.

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ABSTRACT

Deposits of white silica sand and kaolinitic clay of Cretaceous age occur in Windsor age fault-bounded basins in the Shubenacadie, Musquodoboit and Stewiacke Valleys, at Diogenes Brook, Cape Breton Island, and in isolated sinkholes and unconformity fillings within or adjacent to Windsor Group carbonate rocks.

Refraction seismic surveys were successfully used to profile structural basins in order to identify areas potentially favorable for Cretaceous deposits. Diamond-drilling in the most favorable areas outlined significant deposits of Cretacous sand and clay. The Diogenes Brook deposit contains over 7 million tonnes of silica sand, grading >95% SiO_2, within 50 km of a deep water port. The large Musquodoboit Valley deposits extend northeastward along the river valley for about 6 km from Dickey Brook to Kent Brook. Chemical analyses, grain size distribution and analysis of heavy mineral suites were conducted on sand samples from selected deposits. The heavy mineral suites suggest local provenance.

The stratigraphy of the Musquodoboit Valley and Diogenes Brook deposits is complex but some generalizations can be made. The Musquodoboit deposits have a large sand component in the upper parts of the section with clay and lignite contents increasing with depth. They are oxidized to depths of up to 70 m. The Diogenes Brook deposit is predominantly sand.

The Diogenes Brook deposit ranges in age from Valanginian at the base to Albian at the top. Its deposition is correlated with that of the offshore Missisauga Formation which represents a seaward prograding delta complex resulting from the Avalon uplift. This tectonic event may have produced grabens and basins as far east as Cape Breton Island. The Musquodoboit Valley deposits are Aptian or early Albian in age and represent the terrestrial equivalents of the offshore Logan Canyon Formation, deposited in response to a renewed pulse of ocean floor spreading and associated tectonic activity on the Scotian Shelf. During the Late Cretaceous and Tertiary, tilting of the shelf areas resulted in rapid erosion and deep weathering of unconsolidated deltaic sediments and led to deposition of the mudstones and sandstones of the Banquereau Formation. This period of erosion in a subtropical, humid climate produced the silica sand and kaolinitic clay of terrestrial Cretaceous deposits.

Coal compaction tests conducted on lignite samples indicate that Nova Scotia was once overlain by >750 m of sediment. This implies that the northern and western limits of the Cretaceous transgression may have been greater than previously thought, perhaps extending into New Brunswick.

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INTRODUCTION

As one of the world's earliest industrial minerals, fire clay has been used for making pottery since the dawn of mankind. Local sources of such clay are usually well known by inhabitants and as a result they are often recorded on the earliest geological maps. Such was the case with the fire clay deposits of the Musquodoboit Valley which were first reported by E. R. Faribault (1899) on a Geological Survey of Canada map. He cites deposits in the Elmsvale area as being "probably extensive".

H. Ries and J. Keele (1911) published information on an occurrence of silica sand and clay at River Denys, Cape Breton Island. They describe a "deposit of white clay ... near the headwaters of Diogenes Brook, one of the tributaries of the Denys River". At that time small quantities of the clay had been shipped for brickmaking. The white sand was thought to be preglacial and "derived from the igneous rocks which form the upland". The River Denys Sand and Clay Company operated silica sand and clay pits on Diogenes Brook from 1923 to 1925 and this operation was described in a detailed report by Guernsey (1926). Further test work was conducted on the Diogenes Brook sand and described in a report by Carnochan (1931).

Extensive clay deposits were noted by Stevenson (1959) in his geological mapping of the Shubenacadie and Kennetcook map areas. Lignite samples from a clay pit in Shubenacadie were identified as being Early Cretaceous in age. The Nova Scotia Department of Mines undertook an extensive mapping and diamond-drilling program in the Musquodoboit Valley in 1967 (Fowler, 1972; Wright, 1969). Significant deposits of clay and silica sand were drilled at Paint Brook and Elmsvale near Middle Musquodoboit in 1967. Laboratory studies indicated clay grading from low duty refractory to high duty refractory and silica sand suitable for the manufacture of an eighth grade glass. In 1970 the Elmsvale deposit was tricone drilled to a depth of over 150 m (Lin, 1971). Spores obtained from the cuttings of this hole indicated an Early Cretaceous age for the deposit.

Since the Nova Scotia Department of Mines work in the late 1960s other studies have been carried out on the Musquodoboit clays (Benteau, 1973; Dickie, 1975). However, little work was directed towards understanding the characteristics of the deposits, their depositional environment or their extent. This study was designed to answer some of these questions and to provide information which would aid in the search for new deposits of both silica sand and clay.

Seismic profiles were completed over known Cretaceous deposits to determine the morphology of the Carboniferous basins in which they occur. The seismic survey was followed by a diamond-drill program with three drillholes in the Musquodoboit Valley and three drillholes in the Diogenes Brook deposit on Cape Breton Island.

GEOLOGY

GENERAL GEOLOGY

Deposits of silica sand and clay of Cretaceous age are known to occur in the following areas of Nova Scotia (Fig. 1):

1. The Musquodoboit Valley.
2. Shubenacadie, Hants County.
3. West India Road (Brazil Lake), Hants County.
4. McKay Settlement, Hants County.
5. Stewiacke Cross Roads, Colchester County.
6. Belmont, Colchester County.
7. River Denys Basin-Diogenes Brook (Glen Brook), Inverness County.

The Musquodoboit and Diogenes Brook (Glen Brook) deposits have been diamond-drilled and found to extend to depths of 100-200 m below present sea level. Depth of burial determinations on lignite samples taken from these areas indicate that the lignite at one time had been overlain by up to 700 m of sediment (Hacquebard, 1984).

The following is a discussion of the geology of the aforementioned occurrences.

GEOLOGY OF CRETACEOUS DEPOSITS

MUSQUODOBOIT VALLEY

Cretaceous deposits of silica sand and clay have been located in three areas within the Musquodoboit Valley. The largest deposit occurs at Elmsvale and extends from Kent Brook in the east to Dickey Brook in the west, the north is bounded by the steep valley wall and the south by a ridge of high land which extends through the centre of the main Musquodoboit Valley trend. The deposit is over 170 m thick at Elmsvale. A second, smaller occurrence is known at Murphy Brook east of the village of Middle Musquodoboit. The outline of this deposit is not clear but has been mapped by the Nova Scotia Department of Mines as being 1.6 km long by 400 m wide extending north and south along Murphy Brook. The third deposit is located west of Middle Musquodoboit and extends north along McNutt Brook to Glenmore and south to the road joining Chaswood and Middle Musquodoboit. At its greatest width the deposit is 2.4 km from east to west.

The Musquodoboit Valley is underlain by Carboniferous basinal rocks and is flanked on the north and south by Ordovician basement metasedimentary rocks of the Meguma Group. The geology of the basin is well known from the logs of numerous base metal exploration drillholes. This information is shown on a geological map of the Shubenacadie and Musquodoboit Basins (Giles and Boehner, 1982). The basinal rocks are characterized by gypsum, anhydrite, dolostone and mudstone of the Carrolls Corner Formation overlying sandstone, siltstone and dolomitic shale of the Meaghers Grant Formation. These rocks are folded into shallow dipping anticlines and synclines

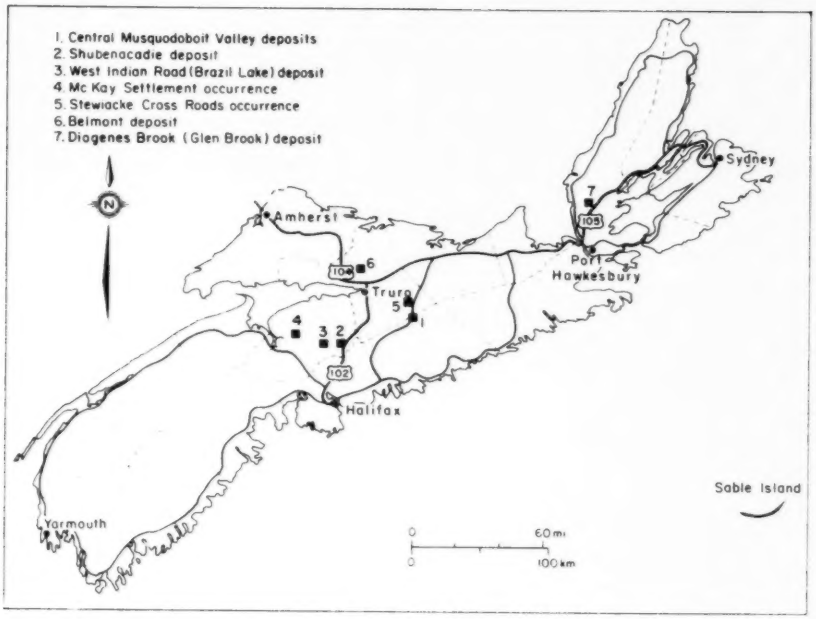

Figure 1. Location map of Cretaceous deposits and occurrences in Nova Scotia.

trending northeast. The basin is dissected by major east and northeast trending faults.

Seismic profiles at Kent Brook, Elmsvale, Dickey Brook and McNutt Brook suggest that the Cretaceous deposits occur in major depressions in the basin and are probably a result of block faulting along the basin margins. The north side of the valley is the deepest with paleoslopes up to 15°.

UPPER STEWIACKE

A small occurrence consisting of silica sand and multicoloured clay is located approximately 1 km north of Stewiacke Cross Roads (Fig. 2). Exploration drilling in the area indicates that the deposit is not extensive, however it is interesting to note that it overlies Carboniferous rocks of the Stewiacke Basin. These Carboniferous rocks include gypsum and anhydrite of the MacDonald Road Formation and sandstone and siltstone of the Meaghers Grant Formation which overlie basement slates and quartzites of the Ordovician Meguma Group. Structurally, the Stewiacke Basin is dissected by northeast trending faults and although the throw on each of these faults is unknown, it is inferred to be small.

WEST INDIAN ROAD (BRAZIL LAKE)

The West Indian Road sand deposit has been described in detail (Stea and Fowler, 1981). Silica sand occurs in what is interpreted to be a large gypsum sink hole in the MacDonald Road Formation (Fig. 3). These rocks overlie sandstone and conglomerate of the Cheverie Formation. Basement rocks consist of slate and quartzite of the Meguma Group.

In contrast to the Musquoboboit deposits, which are larger and occur in fault-bounded basins, the West Indian Road deposit is confined to a large sinkhole. Other sinkholes in the Carboniferous basins could be infilled with silica sand and clay. Such an occurrence is known at the former Esso zinc-lead mine at Gays River, Halifax County (Fowler, personal communication; Davies et al., 1984).

BELMONT

The Belmont silica sand deposit is located 12 km northwest of Truro and 2 km east of the village of Belmont (Fig. 4). Here a small pit has been excavated and several thousand tonnes of sand have been stockpiled. The lateral extent of the deposit has not been determined. The underlying bedrock consists of red Triassic sandstone and siltstone of the Wolfville Formation. Faulting has moved a block of early Carboniferous wacke and siltstone of the Parrsboro Formation into the area north of the deposit.

Structurally, the area is dominated by the Cobequid fault system, a series of east trending faults active since Late Carboniferous time with several episodes of movement having occurred along the system. The rocks on the north side of the fault system consist mainly of

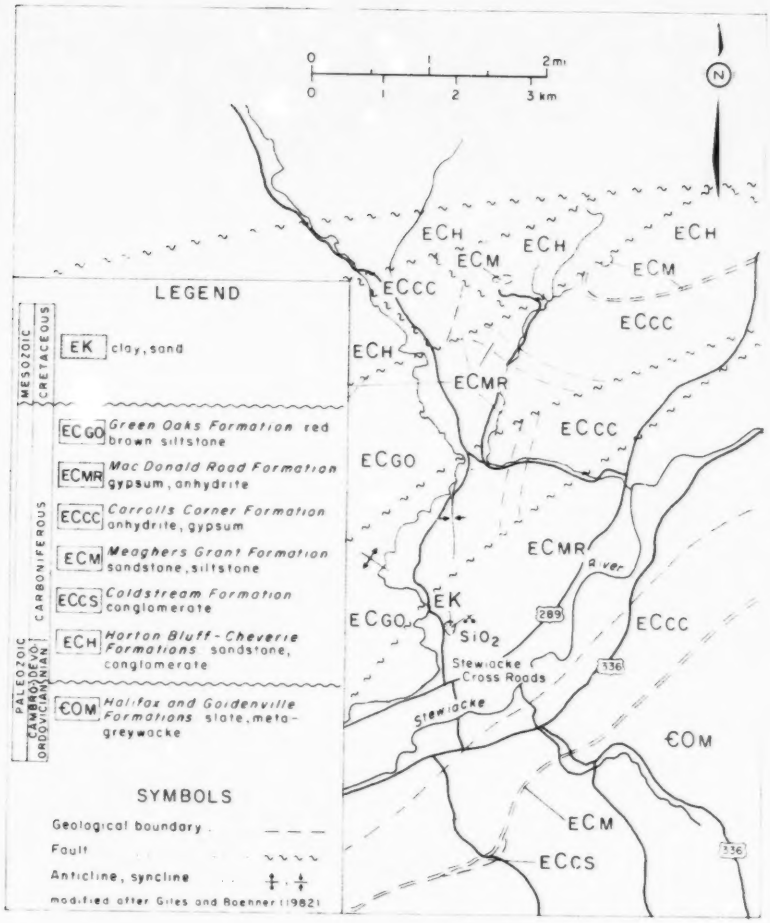

Figure 2. Silica sand deposit, Stewiacke Cross Roads, Colchester County.

Silurian or older volcanic, metasedimentary and granitic rocks (Donohoe and Wallace, 1982).

MCKAY SETTLEMENT

An occurrence of white silica sand of unknown age is located in Hants County 3 km southwest of Upper Newport between the Meander and Little Meander Rivers (Fig. 5). The deposit is exposed in an abandoned gypsum quarry west of the currently operating quarry. Previous drilling by the Nova Scotia Department of Mines in the 1960s indicated silica sand of unknown thickness on the south quarry face. The sand is thought to have been deposited in a sink hole or as an infilling along an unconformity. The occurrence is underlain by gypsum, limestone and red and green shale of the Windsor Group, which is fault bounded to the southeast by basement quartzites and slates of the Meguma Group.

DIOGENES BROOK (GLEN BROOK)

An occurrence of silica sand and clay is located on Diogenes Brook, 3.2 km northwest of the village of Melford (Map 2). Access to the site is provided by a logging road along the west side of Diogenes Brook from Melford. The stream valley is narrow, with several wet areas and sink holes providing a poor road bed. In addition, many bridges have been washed out making access by vehicle during wet periods difficult.

The sand is visible in excavated pits along the north and south sides of the intersection of two tributaries of Diogenes Brook. The deposit was worked during the late 1920s with little evidence of the old operations remaining. Limited stripping with a bulldozer uncovered the entrance to one of the old adits and turned up lengths of rails once used with tram cars to move sand from pit faces to storage (Map 3).

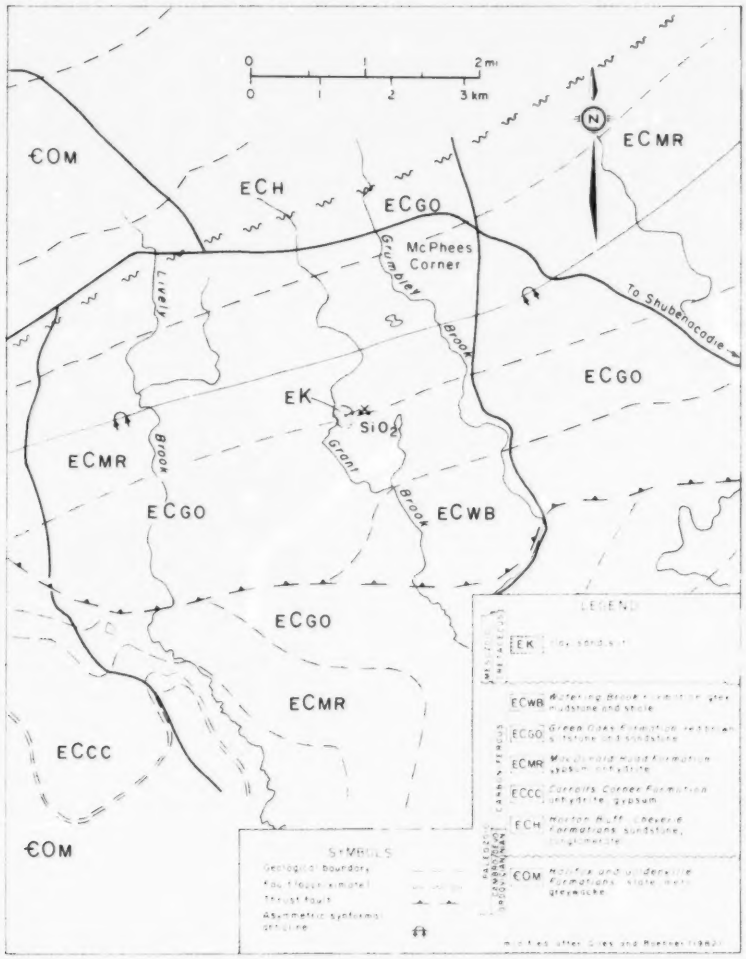

Figure 3. Silica sand deposit, West Indian Road, Hants County.

Diogenes (Glen) Brook rises in the Creignish Hills and flows into the Bras d'Or Lakes. The Creignish Hills are underlain by feldspathic and micaceous quartz schists of the Precambrian George River Group. Also included are limestone and marble, quartzite, and minor volcanic rocks. Locally these rocks have been intruded by quartz monzonite, granodiorite and minor granite of Devonian age. A fault-bounded block of limestone and gypsum of the Windsor Group underlies a 1.6 km long section of Diogenes Brook where the silica sand deposit occurs. Downstream, fault-bounded Windsor Group limestone and gypsum also underlie the flood plain at Upper River Denys and Melford.

The silica sand and clay deposit at Diogenes Brook was initially exposed in the stream bed, constrained by steep walls rising 95 m. The sides of the valley are covered with thick deposits of glacial till and talus. At the intersection of the two tributaries near the old excavations, deposits of ice contact stratified drift occur which could be up to 20 m in thickness. The top of the silica sand appears to be flat lying and is approximately 5 m above the present stream level. The sand does not occur as high terraces on either side of the stream valley, as one might expect from the morphology of the valley walls, and as a consequence only the top 5 m of the deposit could be removed above the water table.

Three diamond-drill holes were collared in the deposit, two to test the thickness of overburden and one to determine the thickness of the deposit itself. The deposit consists of interbedded coarse and fine white sand and clay. It is 125 m thick and overlies a white limestone breccia. On the surface, bedding planes strike

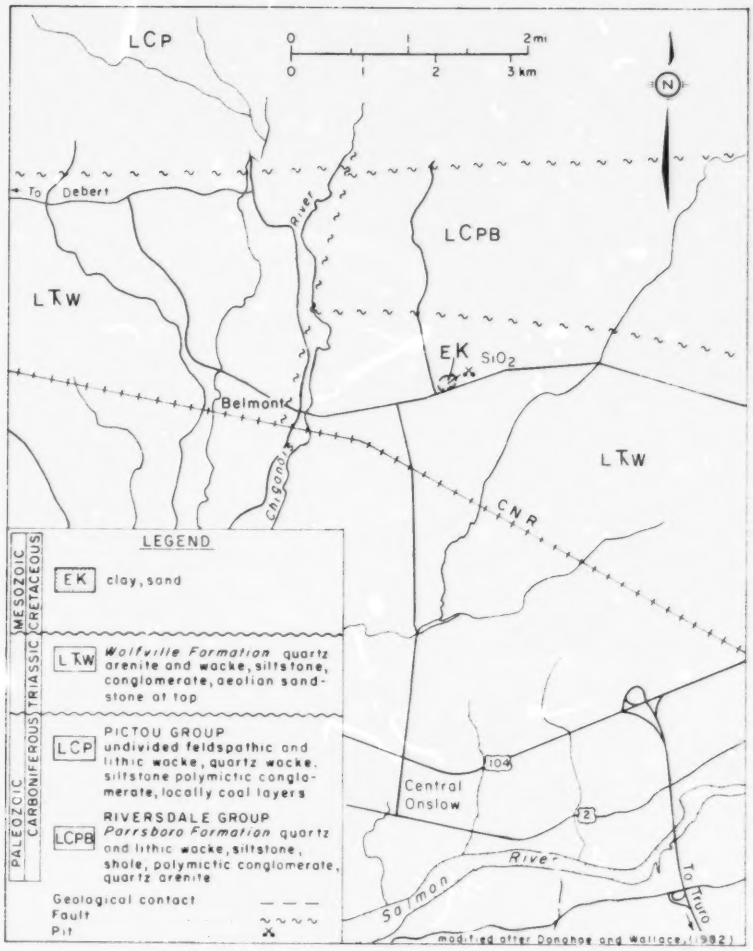

Figure 4. Silica sand deposit, Belmont, Colchester County.

180° and dip 40° east. Age determinations indicate that the deposit is Valanginian in age at the base and early Aptian at the top (Davies, 1983). Compaction tests on lignite beds indicate a minimum depth of burial of 720 m (Hacquebard, 1984). This implies, given the present position of the deposit, that at least 600 m of sediment have been eroded since deposition.

GEOPHYSICAL SURVEYS

INTRODUCTION

One of the primary objectives of this project was to develop exploration techniques which would lead to more accurate predictions of the location of previously undetected silica sand deposits. Exploration of Cretaceous deposits was undertaken by the Ontario Geological Survey in the James Bay Lowlands utilizing seismic profiles across suspected basins with follow-up reverse circulation drilling. Although the type of seismic survey or the geometry of the spreads used was not indicated, it was reported to be a very useful tool in determining depth to bedrock (Telford and Verma, 1979).

Previous drilling in the Musquodoboit Valley of Nova Scotia suggested that some Cretaceous deposits occur in very deep depressions in the present river valleys. In order to determine whether this was true for all Cretaceous deposits in the Musquodoboit Valley it was decided to run seismic profiles at planned locations across the valley. The profiles were run along existing roads and where necessary along cut lines. A total of 13.88 km of seismic profiling were completed during the survey.

EQUIPMENT

A Nimbus ES-1210F 12 channel signal enhancement seismograph was used to perform this survey. Geophone separation on the cable was 25 m. The geophones were 14 hertz units and a total of 12 were used.

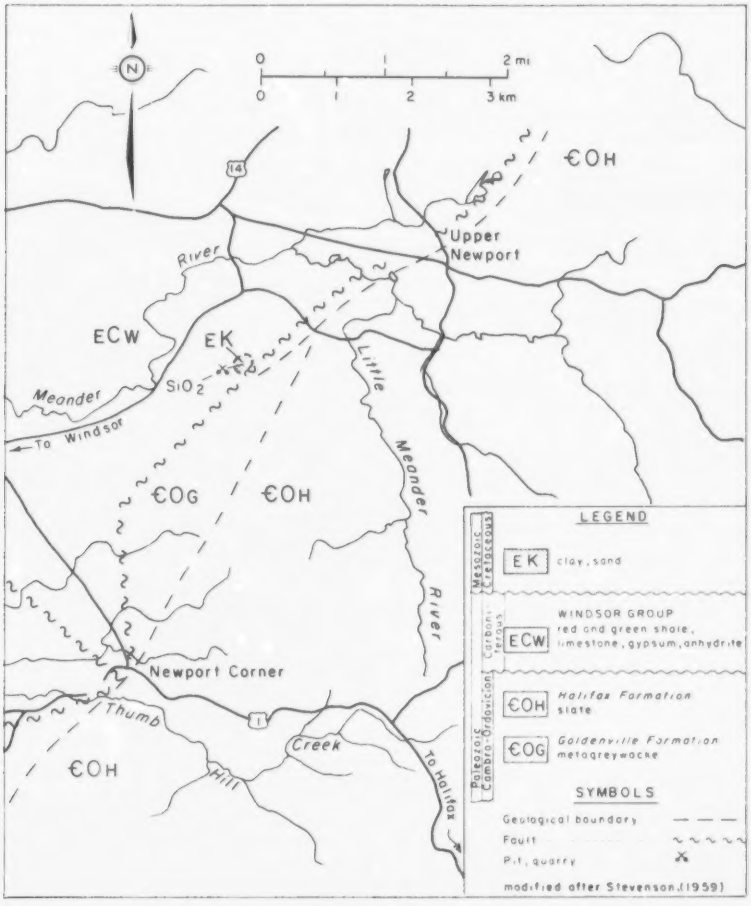

Figure 5. Silica sand occurrence, McKay Settlement, Hants County.

FIELD METHOD

A standard reversed-refraction survey was carried out using 0.25 - 1 kg of Pento-Mex primer as a seismic source. Shot depths at each end of the spreads varied from 0.5 - 1.0 m below surface. Back to back spreads were shot along each seismic profile.

DATA REDUCTION

Data reduction methods are detailed in Table 1. Raw data from the surveys were used to compute layer thickness and depth to bedrock.

DISCUSSION

The average depth to bedrock in the Musquodoboit Valley was estimated at 50-100 m and much less at the margins. As a general rule, spread length should be 3 to 3 1/2 times the critical distance. Therefore spread lengths of 550 m were assumed to be sufficient to "see" to bedrock.

The Nimbus seismograph has stacking capabilities which allow the use of a sledge hammer as a seismic source. For practical purposes the hammer source gives fair records to 175-200 m cable length, which implies a depth to bedrock of approximately 50 m. This proved to be insufficient for our survey as bedrock depths >175 m were encountered in some locations. In fact, in the deepest areas, reversed profiles were extended to 1100 m. Explosive charges consisting of 0.25 - 1 kg of Pentomex were used, which gave good quality records for our spreads of 1100 m. Minimal blowout of charge holes was achieved by placing the charge at a depth of 1 m, compacted well and wet.

Production on the survey consisted of three setups per day or 1.6 km with a four man crew. Where roads were used, the production rate was higher as equipment could be moved more quickly by truck. Where the cable was stretched over ponds and streams, effort was made to keep the cable from being submerged. Although water

Table 1. Data reduction methods for seismic surveys.

Travel times were read from the seismic records and plotted on a time-distance graph, which was used to derive many of the variables. Elevation corrections were applied where necessary. The time intercept method was used to compute layer thickness at the ends of each spread. Layer thickness was computed on a Hewlett Packard 41C programmable calculator using the followi formulae:

$$Z_1 = \frac{Ti_2 V_1}{2 \cos(\sin^{-1} V_1/V_2)}$$

$$Z_2 = \frac{Ti_3 - Ti_2 \dfrac{\cos(\sin^{-1} V_1/V_3)}{\cos(\sin^{-1} V_1/V_2)} V_2}{2 \cos(\sin^{-1} V_2/V_3)}$$

where Z_1 and Z_2 = first and second layer thickness
V_1, V_2, V_3 = velocities of layers 1, 2, and 3
Ti_2, Ti_3 = time intercept from V_2 and V_3

The delay time method was used to compute additional depths under some of the geophones that had an overlap between arrivals from the same layer (Redpath, 1973). The formulae used are:

$$Z_D = \frac{\Delta T_D V_1}{\cos(\sin^{-1} V_1/V_2)}$$

where ΔT_D= delay time at the geophone for the three layer case
$\Delta T_D = 1/2(T_{D1}+T_{D2}-T_t)$
Z_D = depth to bedrock, calculated by delay time method
T_{D1}, T_{D2} = first and second arrival times in regions of refraction overlap
T_t = total time at end of geophone spread

For the three layer case:

$$Z_2 = \frac{(\Delta T_{12} - \Delta T_1) V_2}{\cos(\sin^{-1} V_2/V_3)}$$

where ΔT_{12} is the combined delay time for the first and second layers and ΔT_1 is the delay time for the first layer.

True velocities of dipping layers were calculated using the harmonic mean multiplied by the cosine of the dip angle:

$$V_2 = \frac{2 V_{2U} V_{2D}}{V_{2U} + V_{2D}} \cos Y$$

Where V_{2U}= up-dip velocity (apparent)
V_{2D}= down-dip velocity (apparent)
Y = dip angle

True velocities must be used to compute depths. Apparent velocities will result in erroneous depths.

A sample calculation complete with seismic records is included in Appendix 1 of this report.

resistant, cable insulation and armour become worn and deteriorate with use.

Back to back spreads give verification of depth to bedrock under the shot point. Uncertainties occur where depth to bedrock changes significantly between spreads. Such difficulties were experienced on this survey between profiles 1A, B and C (Map 1b).

This survey used precise levelling for topographic corrections but barometers would be sufficiently accurate for plotting sections within 2-3 m. Precise depth to bedrock determinations are generally not possible with this type of refraction survey, so a two barometer survey with a base station and a moving meter would be sufficient.

Once general profiles have been obtained using refraction seismics, more precise layer thickness determinations are obtainable with reflection seismics. However, reflection techniques are less productive and sophisticated data processing equipment is required. With reflection seismics there are added difficulties in field checking the results and the geometry of spreads must be set by experimenting in the field. In summary, refraction seismic methods are best suited for regional work where approximate depth to bedrock outlines basin shape and production is high. Reflection seismic methods are best suited for detailed layer thickness determinations and are hampered by low productivity and more difficult data processing.

Velocities of various rock and overburden types determined by this survey are as follow:

(a) overburden above water table - 1100-1400 m/s
(b) Cretaceous deposits (clay, sand - water saturated) - 1700-1900 m/s
(c) Meguma quartzite - 4400-4800 m/s
(d) Windsor Basin limestone, gypsum, mudstone - 3200-3800 m/s
(e) Windsor Basin massive limestone or anhydrite - 4100-4700 m/s

DIAMOND-DRILLING

INTRODUCTION

In March and April of 1982 the Nova Scotia Department of Mines and Energy contracted Logan Drilling Limited of Middle Musquodoboit, Halifax County, to drill two holes in the Pleistocene and Cretaceous deposits of the Musquodoboit Valley. The holes were collared at Paint Brook and Elmsvale (Map 1a). These drillholes provided initial stratigraphic information and depth to bedrock determinations which aided in the interpretation of seismic data carried out during the month of June.

During October of 1982 the Drilling Division of the Nova Scotia Department of Mines and Energy drilled three holes at Diogenes Brook, Inverness County (Map 2). Two holes were collared south of the main brook and one hole was drilled just north of the brook at the entrance to the old adit (Map 3).

In addition, the Nova Scotia Department of Mines and Energy completed a hole at McNutt Brook (Map 1b) in the Musquodoboit Valley in October 1982. In early November Logan Drilling Limited completed one hole at Dickey Brook and another at Elmsvale (McCabe property).

Altogether eight holes were drilled totalling 780 m. The Nova Scotia Department of Mines and Energy drilled 250 m and Logan Drilling Limited was contracted to drill 530 m. This section outlines the technical problems encountered in drilling unconsolidated sand and clay deposits and summarizes the stratigraphy of Cretaceous deposits in the Musquodoboit Valley and Cape Breton Island.

EQUIPMENT

All holes were drilled with a Longyear 38 or equivalent wireline diamond-drill. The first hole, at Paint Brook, began using a split spoon sampler. However, this technique was inefficient and was changed to standard diamond-drilling procedures. All holes were drilled using BQ and NQ coring rods on the wireline drill. The compact clay cored very well and return was initially 100% in sections of clay over 3 m in thickness. However, water circulation was a problem when drilling through the unconsolidated silica sand layers. To solve this problem, a synthetic polymer (Alcomer) was added to the water circulation which helped seal off the wall of the hole and float the sand to the surface. Provided sufficient polymer was used, few problems were encountered with either loss of circulation or sand return. It was necessary in all holes drilled to run casing to the top of the Cretaceous sediments and often up to 30 m into the clay and sand. Where additives failed to provide water circulation, casing reamed to the problem area usually returned circulation.

Sand sample collection was carried out by attaching a tee to the top of the casing and collecting the water return in a sump. The sump was simply an NQ core box on a slant over which the water and sand mixture flowed. The sand settled to the bottom of the box and was bagged in plastic sample bags at 3 m intervals. After each sample was collected the box was carefully washed out to avoid contaminating subsequent samples. Clay sections were collected in the core tube and stored, wrapped in plastic to prevent moisture loss, in standard core boxes. The most common problems encountered during the drilling were loss of circulation after the drill was shut down at night and loss of circulation due to use of insufficient Alcomer. To solve these problems, further drilling programs should operate on a two shift basis 24 hours a day and a mud mixing tank and mixer should be used to make up an adequate mixture of Alcomer and water to seal the hole.

LITHOSTRATIGRAPHY

Previous detailed diamond-drilling of the Musquodoboit clay and sand deposits (Fowler, 1972) suggested a complex stratigraphy of flat lying, gently dipping to steeply dipping beds of

silica sand, clay, silty clay and silt. The clay ranged in colour from buff to red to brown to black with interbeds of lignite and pyrite nodules at contacts between the buff to ochrous clay and underlying silica sand.

Field examination of silica sand exposures in the Brazil Lake deposit (Stea and Fowler, 1981) has revealed two fining upward sequences 4 m thick, ranging from a cobble gravel at the base and grading into sandy mud. Red-brown staining was found to crosscut bedding near the top of the sequence.

Drillholes were collared at Elmsvale, Paint Brook, McNutt Brook, Dickey Brook and the McCabe property (Maps 1a, 1b). With the exception of the McNutt Brook hole, drilled near the northwestern edge of the valley, all others were drilled in the deepest part of the valley. Seismic information suggests that the holes were drilled near a steep fault scarp trending parallel to the northwestern side of the Musquodoboit Valley. Stratigraphic relationships among the Cretaceous deposits in different areas of the Musquodoboit Valley are difficult to establish because of the limited drilling done during this survey. Although it is not possible to correlate sections in detail, similarities have emerged.

In addition to the Musquodoboit holes, three holes were drilled into a silica sand deposit at Diogenes Brook (Glen Brook) on Cape Breton Island. Due to the distance between the two areas, they will be considered separately for stratigraphic discussions.

ELMSVALE

The Elmsvale drillhole was collared in 10 m of red boulder till. Underlying the till was a complex section of interlaminated silt, sand and clay with individual sand units up to 10 m thick. Bedrock was reached at 81 m and consisted of interlaminated mudstone, limestone and limy mudstone of Carboniferous age. The drillhole had a higher sand component in the top 50% and became organic rich with lignite layers and black clay in the bottom 50%. The clay units near the top of the hole were red and brown whereas they were grey and black near the bottom. The colour change may be a reflection of oxidation of sulphides by circulating ground water.

PAINT BROOK

This drillhole was collared in a buff, red-grey silty clay up to 11 m in thickness and underlain by a further 20 m of red-brown silty clay. Below that the section consisted of predominantly grey to black clay and silty clay with black lignite bands. A section of mottled red and brown clay was cored between 95 and 104 m. Bedrock, consisting of finely laminated gypsum and limestone, was intersected at 105 m.

MCCABE #1

To date, the thickest section of Cretaceous clay and sand was cored in the McCabe #1 drillhole. The section comprised 25 m of brown clay till overlying 163 m of interbedded sand and clay. Bedrock was limy mudstone and was intersected at 188 m. The section was dominated by grey and white silica sand, ochrous red and brown silty clay and mauve, buff, yellow and red silty clay and silt to a depth of 92 m. From that point the section consisted of green and grey clay containing lignite and pyrite nodules to a depth of 188 m. The section from 160-180 m consisted of light grey and green clay and silt.

DICKEY BROOK

The Dickey Brook drillhole was collared in red-brown clay till, which was 38 m thick. The till was underlain by a 72 m section of Cretaceous sand and clay. This Cretaceous section consisted of 30 m of mottled blue, red and mauve silty clay and sand on top of 40 m of grey to black clay, silt and sand. The hole terminated in 10 m of black silty clay and lignite.

MCNUTT BROOK

This drillhole was collared on the western margin of the Musquodoboit Valley at the edge of the Cretaceous deposits. 15 m of glacial till were found to overlie 40 m of light grey silty clay and silt. The top 10 m of clay were slightly more oxidized than the deeper sections, as indicated by the colour. Bedrock, consisting of mudstone collapse breccia, was intersected 55 m below surface.

DIOGENES BROOK (GLEN BROOK)

Three holes were drilled at Diogenes Brook to determine the thickness of sand and clay in the stream valley. The first drillhole was collared in white silica sand and continued mostly in sand to a depth of 92 m. Dark grey plastic clay and lignite was cored from 92-119 m The bedrock was a white to grey mudstone breccia. The other two holes were drilled to determine the lateral continuity of the sand. They also showed that the top of the Cretaceous sand was a virtually flat surface overlain by thick terraces of Pleistocene sand, gravel and till.

PALYNOLOGY

A palynological evaluation carried out on selected samples from Musquodoboit and Cape Breton by Mr. Edward Davies of the Eastern Petroleum Geology Section of the Bedford Institute of Oceanography has established the age of several deposits of silica sand and clay. Spores were recovered from both lignite and sand and clay core samples for microscopic examination. Recovery of spores ranged from excellent to poor.

A stratigraphic chart showing formal divisions of the Cretaceous Period is given in Figure 6. The sand and clay deposits of the Musquodoboit Valley are characterized by a thick sequence of late Aptian to early Albian sediments overlying a lower section of reworked Viséan age sediments. Samples collected from drillholes in

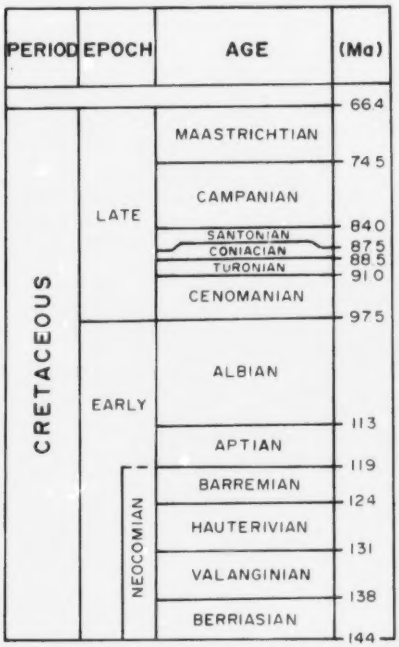

Figure 6. Stratigraphic divisions of the Cretaceous (after Palmer, 1983).

Diogenes Brook indicate a thick section of late Aptian to early Albian sand and clay overlying sediment with Valanginian to Barremian age spores. This deposit represents the first documented occurrence of Neocomian terrestrial sediment in Eastern Canada. The details of each hole sampled are presented in Table 2.

SUMMARY

The stratigraphy of the Cretaceous deposits of Nova Scotia is complex and individual units are difficult to trace, however, some generalizations can be made. The deep drillholes in the Musquodoboit Valley have a large sand component in the upper portions whereas clay and lignite increase with depth. The deep drillhole at Diogenes Brook is similar to the Musquodoboit holes but has more sand. The upper sections of all drillholes in the Musquodoboit Valley are oxidized to depths of up to 60-70 m. This may be a result of ground water circulation which promotes oxidation of iron sulphide. The Cretaceous deposits were found to be essentially flat lying and covered by Pleistocene detritus. Palynological analyses of the deposits showed the sediments to be of Valanginian to Albian age, including the first reported Neocomian terrestrial sediment in Eastern Canada.

GEOCHEMISTRY AND MINERALOGY

INTRODUCTION

The grain size distribution and chemistry of the Musquodoboit and Brazil Lake deposits have been studied and documented by various authors (Fowler, 1972; Stea and Fowler, 1981). Chemical analyses of Elmsvale sand vary from 88-98.2% SiO_2. Samples of sand from Brazil Lake have been reported to contain over 99% SiO_2. For the purposes of this study, sieve analyses were done on samples from drillholes at Elmsvale, Paint Brook and Diogenes Brook and chemical analyses for SiO_2, Al_2O_3, Fe_2O_3, TiO_2 and S were done on Diogenes Brook samples.

Studies were conducted on heavy mineral suites collected from deposits at Elmsvale, Paint Brook, Diogenes Brook and Belmont. This work, although limited in scope, was designed to provide information on provenance of the silica sands. Similar studies on the Brazil Lake deposit (Stea and Fowler, 1981) and the Shubenacadie deposit (Benteau, 1973) provide some background suites which were helpful in interpreting the results of this work.

GRAIN SIZE ANALYSIS

Samples of sand were collected from major sand units in the Elmsvale and Paint Brook sections and the weight percentage of various mesh size ranges was determined. In addition, the upper 30-35 m of the Diogenes Brook deposit were sampled from the three drillholes and analyzed. Sieve analysis obtained 13 size fractions, ranging from +4 to -250 mesh.

The results of this work, shown in Table 4, indicate that at least 70-80% of the sand in the Elmsvale and Paint Brook deposits is coarser than 100 mesh while 80% of the Diogenes Brook deposit is coarser than 80 mesh. In drillhole #2 at Diogenes Brook, the section from 11-14 m contains 28.2% material finer than -250 mesh. Similarly the sample interval from 64.17-65.1 m in the Paint Brook #1 drillhole contains 55.5% material finer than -250 mesh.

It is clear from this work that there is considerable variation in grain size over small sample intervals for the Musquodoboit deposits and less variation in grain size for the Diogenes Brook deposit.

CHEMICAL COMPOSITION

Silica sand used in the glass manufacturing industry must have a high silica content and be low in contaminants such as Al, Fe, Ti and S. The chemical composition of the Elmsvale sand is well known (Fowler, 1972) as is the composition of the Brazil Lake sand.

Samples were collected from three drillholes in the Diogenes Brook deposit at 3 m intervals and analyzed for SiO_2, Al_2O_3, Fe_2O_3, TiO_2 and S (Table 5). Hole #1 was sampled from 5-35 m and produced an average SiO_2 content of 96.12%. The average contents of Fe_2O_3 and Al_2O_3 were low as were TiO_2 and S. It should be noted that the sample interval from 5-8 m was probably contaminated with surface till, hence the lower SiO_2 value. Hole #2 was analyzed over the interval 7-29 m with essentially the same results. In this drillhole mixing of overlying till with the sand is evident over the interval 7-14 m. Hole #3 was collared on undisturbed

Table 2. Age determinations of selected core samples. (GSC D2465, D2466)

Drillhole	Interval (m)	Age	Comments
Paint Brook 1	33.0 - 33.12	Pleistocene	Subtropical terrestrial flora with fresh water algal cysts. At 59.15 a species of probable marine dinoflagellate cyst was observed
	33.74-105.53	Late Aptian to Earliest Albian	
	110.57-110.67	Viséan	
Elmsvale 1	33.84- 33.49	Cretaceous and Quaternary	
	33.39- 58.88	Aptian-Early Albian	
	74.9 - 90.76	Carboniferous	Assemblage zone 2 of Windsor Group
	106.98-107.08	Carboniferous	
	112.98-113.08	Carboniferous?	
Dickey Brook	103.31-108.02	Early Aptian	
Diogenes Brook	Surface-6	Aptian to early Albian	
	6-10	Late Aptian to early Albian	
	10-42	no recovery	
	43-75	no. recovery	
	75-95	Barremian to early Aptian	
	97-119.5	Valanginian	First occurrence of Neocomian terrestrial sediment reported in Eastern Canada

white sand and had a more uniform SiO_2 grade from top to bottom. The SiO_2 content in this drillhole ranged from 94.4% - 97.9%.

HEAVY MINERAL ANALYSIS

Heavy mineral suites were microscopically analyzed from samples collected from the Elmsvale, Paint Brook, Diogenes Brook and Belmont deposits. Approximately 500 g of the -10 to +250 mesh fraction was processed through tetrabromoethane to remove mineral fragments heavier than 2.95 specific gravity. The heavy mineral grains were then mounted in epoxy and polished thin sections were made.

The heavy mineral suite from the Musquodoboit Valley differs considerably from the Diogenes Brook and Belmont suites (Table 3). The Musquodoboit suite contained a high percentage of ilmenite, magnetite and pyrite with minor staurolite, tourmaline and zircon. Other minor constituents not common to all samples were hematite, limonite, marcasite and quartz intergrown with sulphides. Grain size varied from fine to coarse with many samples equigranular. The Diogenes Brook samples contained only 40% opaques of which magnetite made up the highest percentage. Ilmenite was also common. Minor constituents included amphibole, staurolite, tourmaline, zircon, garnet, hematite and limonite. The Diogenes Brook sample contained no pyrite or marcasite, in contrast to the Musquodoboit sample. Grain size varied from coarse to fine with most grains subangular to angular. The Belmont sample was an exception, containing mostly rounded grains, equigranular and medium grained. Over 80% of the heavy mineral fraction was ilmenite with minor constituents being staurolite, two types of

Table 3. Composition of heavy mineral suites of selected sand samples.

	Staurolite	Tourmaline (Blue)	Tourmaline (Rose Brown)	Zircon	Ilmenite	Magnetite	Pyrite	Garnet	Pyroxene	Amphibole	Chromite	Hematite	Chlorite	Quartz	Muscovite	Marcasite	Rutile	Cassiterite	Corundum	Allanite	Feldspar	Limonite	Chalcopyrite	Sphene	Biotite	COMMENTS
E.V.1 13.64-15.5	Tr	-	Tr	-	30	Tr	40	-	-	-	-	-	-	Tr	-	-	Tr	-	Tr	-	-	30	-	-	-	Subrounded opaques, many intergrown with quartz. More coarse grained than others.
E.V.1 22.01-15.5	Tr	-	Tr	-	60	5	10	-	-	-	-	-	-	Tr	Tr	-	-	-	-	Tr	-	Tr	-	-	-	Subangular to rounded grains. Coarse size.
E.V.1 31.62-32.86	Tr	-	Tr	Tr	20	20	30	-	-	-	-	-	-	-	Tr	-	-	-	-	-	-	Tr	Tr	-	-	Subrounded. Not as equigranular as other E.V. slides.
E.V.1 37.20-38.27	Tr	-	Tr	Tr	50	30	10	-	-	-	-	-	Tr	-	-	10	-	-	-	-	-	-	-	-	-	Subangular to subrounded.
E.V.1 42.16-43.09	Tr	-	Tr	Tr	20	-	50	-	-	-	-	10	-	-	-	-	-	Tr	-	-	-	-	-	Tr	-	Subrounded, equigranular.
E.V.1 47.43-48.05	Tr	-	Tr	Tr	50	30	20	-	-	-	-	-	-	Tr	Tr	-	-	-	-	-	-	-	-	-	-	
E.V.1 52.08-54.87	Tr	-	Tr	Tr	10	40	30	-	-	-	-	-	-	Tr	-	20	-	-	-	-	-	-	-	-	-	Highly variable in grain size. Subangular fragments
E.V.1 64.17-67.27	Tr	-	Tr	Tr	Tr	30	-	-	-	-	-	-	-	-	-	70	-	-	-	-	-	Tr	-	-	Tr	Medium grained, rounded to subrounded. Equigranular. Colloidal marcasite.
E.V.1 67.27-68.51	Ab	-	Ab	-	15	15	60	-	-	-	-	-	-	Tr	-	Tr	-	-	-	-	Tr	-	-	-	-	Medium grained, subrounded.
E.V.1 116.87-119.47	-	-	Tr	Tr	-	40	30	-	-	Tr	-	-	Tr	Tr	Tr	-	-	-	-	-	Tr	Tr	-	-	-	Variable grain size, coarse-fine. About 40% non opaques.
P.B.1 3.41-4.64	Tr	-	Tr	Tr	80	20	-	-	-	-	-	-	-	Tr	-	-	-	-	-	-	-	-	-	-	-	Medium grain size, coarse-fine. About 40% non opaques.
P.B.1 10.85-12.09	Tr	Tr	Tr	Tr	75	20	-	-	-	-	-	-	-	Tr	Tr	-	-	-	Tr?	-	-	-	-	-	Tr	Rounded to subangular, fine- to medium-grained.
P.B.1 64.17-65.1	Tr	-	Tr	Tr	30	30	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Tr	Fine grained, subrounded, equigranular.
P.B.1 70.37-68.28	Tr	-	Tr	Tr	70	10	20	-	-	-	-	-	Tr	Tr	-	-	-	-	-	-	-	-	-	-	-	Rounded-subrounded, equigranular, medium grain size.
P.B.1 92.07-96.10	Tr	-	Tr	Tr	20	10	70	-	-	-	-	-	-	Tr	-	-	-	Tr	-	-	-	-	-	-	-	Fine grained, subrounded-rounded.
Diogenes Brook	x	-	x	x	10	30	-	x	-	Ab	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	40% opaques, subangular to angular, coarse to fine grain size.
Belmont	x	x	x	x	80	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rounded grains, medium grained, equigranular.

(Tr), x - Present
Ab - Abundant
70 - % opaques
- - not present

Table 4. Results of screen analyses of selected drillhole sand samples. Values are expressed in per cent.

Diogenes Brook Hole # 1

Mesh Size	Sample Interval								
	5-8m	8-14m	14-17m	17-20m	20-23m	23-26m	26-29m	29-32m	32-35m
+4	Nil	Nil	0.1	<.1	Nil	0.2	Nil	<.1	<.1
-4 +8	<.1	<.1	0.2	0.1	<.1	0.4	0.3	0.2	0.2
-8 +10	<.1	<.1	0.6	0.5	0.3	2.2	1.8	2.1	1.5
-10 +10	0.1	1.4	2.7	4.6	2.1	13.2	11.4	19.4	16.5
-14 +20	0.4	5.9	5.2	8.3	1.4	12.5	15.2	23.4	14.9
-20 +24	0.4	6.6	5.9	7.7	0.8	5.4	12.2	13.9	9.7
-24 +32	2.2	26.8	18.2	26.7	1.9	12.1	28.3	22.4	19.5
-32 +60	49.0	46.9	50.9	44.8	54.8	27.9	27.4	15.6	28.3
-60 +80	23.5	4.9	11.7	2.5	25.4	13.3	1.0	0.6	2.2
-80 +100	6.0	0.5	1.1	0.3	4.1	3.5	0.1	<.1	0.3
-100 +200	6.7	0.4	0.6	0.3	3.3	3.7	0.1	<.1	0.3
-200 +250	0.1	Nil	0.1	0.1	0.2	Nil	Nil	Nil	Nil
-250	11.5	6.5	2.7	4.1	5.7	5.6	2.2	2.3	6.6

Diogenes Brook Hole # 2

Mesh Size	Sample Interval						
	7-11m	11-14m	14-17m	17-20m	20-23m	23-26m	26-29m
+4	Nil	0.3	Nil	Nil	Nil	Nil	<.1
-4 +8	0.8	1.7	0.6	<.1	<.1	0.5	0.9
-8 +10	4.5	3.2	1.8	<.1	0.4	3.3	2.7
-10 +10	30.5	20.4	10.8	0.6	8.8	28.2	27.7
-14 +20	16.6	10.3	12.0	2.3	15.5	18.9	22.6
-20 +24	7.0	5.6	8.2	3.7	10.5	9.9	10.9
-24 +32	12.0	10.7	19.1	20.5	20.7	15.4	15.2
-32 +60	15.0	16.8	37.3	62.1	36.4	16.5	13.7
-60 +80	3.3	2.2	2.4	4.9	3.6	1.5	0.6
-80 +100	1.0	0.3	0.2	0.9	0.5	0.3	<.1
-100 +200	1.4	0.3	0.1	1.2	0.4	0.3	Nil
-200 +250	0.1	Nil	Nil	0.1	Nil	Nil	Nil
-250	7.8	28.2	7.5	3.6	3.2	5.2	5.7

Diogenes Brook Hole # 3

Mesh Size	Sample Interval						
	4-5m	5-8m	8-11m	11-14m	14-17m	17-20m	20-23m
+4	0.4	0.2	Nil	0.2	<.1	0.1	<.1
-4 +8	0.3	0.1	0.1	0.7	<.1	<.1	<.1
-8 +10	1.6	0.9	0.3	0.2	<.1	0.1	<.1
-10 +10	14.4	16.6	5.0	0.8	0.1	3.2	0.4
-14 +20	21.2	19.2	6.6	1.0	0.6	6.2	1.1
-20 +24	11.3	.34.	5.8	1.0	1.1	5.3	1.6
-24 +32	16.6	22.6	19.4	1.1	6.1	15.8	9.8
-32 +60	15.0	17.7	45.8	43.4	65.0	50.5	51.0
-60 +80	4.2	3.5	8.9	19.2	18.7	11.3	17.9
-80 +100	1.1	1.0	1.6	6.2	2.2	2.0	4.4
-100 +200	0.7	0.9	1.3	9.5	1.4	1.3	4.1
-200 +250	0.1	<.1	Nil	0.5	Nil	Nil	0.2
-250	13.1	3.9	5.2	16.2	4.8	4.2	9.4

Elmsvale Hole # 1

Mesh Size	Sample Interval															
	(18.29-20.15m)	(20.15-22.01m)	(22.01-23.25m)	(31.62-32.86m)	(32.86-34.4m)	(34.4-35.65m)	(35.65-37.2m)	(37.2-38.27m)	(42.16-43.09m)	(43.09-44.95m)	(44.95-46.19m)	(46.19-47.43m)	(47.43-48.05m)	(52.08-54.87m)	(64.17-67.27m)	(67.27-68.51m)	(116.87-119.97m)
+4	Nil	Nil	<0.1	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	11.1
-4 +8	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	0.3	1.4	<0.1	<0.1	Nil	3.1
-8 +10	0.1	<0.1	0.2	<0.1	<0.1	1.5	0.3	0.1	0.4	0.1	0.3	1.5	3.4	0.1	0.1	<0.1	2.2
-10 +14	0.3	0.1	1.2	0.6	0.5	4.5	1.2	0.9	0.7	1.5	1.1	3.9	14.6	1.5	1.6	1.4	3.2
-14 +20	3.1	1.6	4.7	3.0	3.0	7.5	6.0	4.5	0.8	0.7	4.2	10.0	27.2	4.4	8.1	7.8	2.8
-20 +24	4.2	2.9	5.7	4.1	5.0	5.3	7.2	5.4	1.0	0.3	4.7	6.9	14.1	3.6	6.0	5.9	2.1
-24 +32	16.3	14.1	19.6	14.2	18.9	13.4	18.7	15.0	5.8	1.1	13.4	17.4	15.9	11.5	12.7	11.4	5.5
-32 +60	45.3	46.8	44.5	36.8	43.0	34.8	37.3	36.2	23.2	17.1	34.3	31.1	10.7	33.3	29.2	31.9	21.2
-60 +80	13.2	18.0	12.7	16.2	12.9	15.5	14.4	17.0	11.9	23.9	15.8	8.9	3.9	16.3	11.5	17.1	10.2
-80 +100	4.0	5.1	3.4	6.9	4.2	5.7	4.5	7.2	5.8	11.4	5.2	2.7	1.5	7.4	4.7	5.6	4.1
-100 +200	5.2	5.5	3.4	9.5	6.2	7.5	6.0	10.2	12.2	19.4	8.2	4.7	2.0	11.3	9.2	7.4	8.3
-200 +250	0.4	0.4	0.2	0.6	0.4	0.2	0.3	0.6	1.3	1.1	0.6	0.6	0.2	0.1	1.2	<0.1	0.2
-250	7.9	5.5	4.4	8.1	5.9	4.0	4.1	2.9	36.9	23.3	12.2	12.0	5.1	10.5	15.7	11.5	26.0

Table 4. Results of screen analyses of selected drillhole sand samples (continued).

Paint Brook Hole #1

Mesh Size	Sample Interval													
	(3.41-4.64m)	(4.64-5.89m)	(5.89 7.13m)	(7.13-8.37m)	(8.37-9.61m)	(9.61-0.85m)	(10.85-12.09m)	(64.17-65.1m)	(65.1-68.28m)	(68.28-70.37m)	(92.07-96.1m)	(13.64-15.5m)	(15.5-17.36m)	(17.36-18.29m)
+4	1.9	3.4	1.6	2.9	2.9	1.6	2.6	<0.1	0.7	Nil	Nil	1.8	Nil	Nil
-4 +8	10.6	10.6	10.5	11.7	13.0	13.7	13.4	<0.1	0.6	0.3	Nil	5.7	<0.1	0.2
-8 +10	7.8	7.0	8.1	7.9	10.0	11.2	10.2	<0.1	0.2	0.2	<0.1	5.1	<0.1	1.3
-10 +14	7.3	8.9	8.0	10.3	12.9	13.7	12.7	0.1	0.1	0.2	0.1	8.3	1.2	6.3
-14 +20	9.5	8.8	9.4	10.7	12.0	12.3	7.4	0.1	0.2	0.2	0.1	7.3	9.9	14.3
-20 +24	5.4	5.2	5.2	5.6	5.8	5.8	3.7	<0.1	0.1	0.2	0.1	4.3	11.1	7.0
-24 +32	10.8	10.9	10.5	10.8	10.2	8.9	7.1	0.2	0.6	2.4	0.2	9.2	24.2	12.5
-32 +60	20.2	21.8	21.5	16.2	14.2	11.5	18.4	5.9	13.9	50.6	5.2	31.5	29.9	31.9
-60 +80	6.3	7.0	6.7	6.1	4.5	4.5	5.8	12.4	20.7	15.6	11.4	10.5	6.1	12.4
-80 +100	2.5	2.4	2.2	2.6	2.1	2.0	2.0	8.9	8.3	8.7	8.3	2.3	1.8	4.0
-100 +200	5.0	4.9	3.9	5.5	5.3	4.9	3.7	16.5	24.8	10.7	15.6	2.7	3.5	4.8
-200 +250	0.6	0.4	0 4	0.7	0.8	0.6	0.2	0.4	3.2	0.2	1.7	0.1	0.4	0.4
-250	12.4	8.7	12.0	9.0	6.3	9.3	12.8	55.5	26.6	10.7	57.3	11.2	11.9	4.9

Grab Samples

Mesh Size	Belmont #1	Upper Stewiacke #1	Diogenes Brook #1
+4	1.2	1.4	0.3
-4 +8	2.6	6.2	0.1
-8 +10	2.3	6.3	0.1
-10 +14	3.8	8.3	0.6
-14 +20	10.0	10.5	1.8
-20 +24	8.7	6.4	2.4
-24 +32	22.1	13.9	11.9
-32 +60	25.1	23.0	20.0
-60 +80	4.3	6.0	4.0
-80 +100	1.4	2.1	2.3
-100 +200	2.3	4.1	5.1
-200 +250	0.2	0.2	0.9
-250	16.0	11.6	50.5

Table 5. Chemical analyses of selected sand samples from Diogenes Brook. Values are expressed in per cent.

Sample		SiO_2	Fe_2O_3 (Total Fe)	Al_2O_3	TiO_2	S
Drillhole #1	5-8M	93.5	0.62	3.17	0.20	.003
	8-14M	97.2	0.59	1.23	0.08	.002
	14-17M	97.0	0.70	1.42	0.08	.003
	17-20M	97.7	0.41	1.21	0.06	.018
	20-23M	93.0	2.06	2.12	0.35	.009
	23-26M	94.4	2.40	1.73	0.12	.024
	26-29M	97.9	0.48	0.76	0.04	.001
	29-32M	98.0	0.89	0.44	0.14	.004
	32-35M	96.4	0.79	1.25	0.12	.002
Drillhole #2	7-11M	80.2	3.29	6.54	0.47	.032
	11-14M	92.2	1.82	2.22	0.13	.013
	14-17M	97.0	0.53	1.17	0.12	.089
	17-20M	97.7	0.41	1.23	0.06	.016
	20-23M	97.9	0.61	0.81	0.07	.010
	23-26M	98.2	0.51	0.79	0.06	-
	26-29M	97.6	0.61	1.08	0.08	-
Drillhole #3	4-5M	95.3	0.66	0.91	0.18	.035
	5-8M	97.9	0.54	1.40	0.10	.042
	8-11M	96.9	0.45	2.04	0.27	.085
	11-14M	94.7	0.68	1.44	0.11	-
	14-17M	96.4	0.51	1.40	0.13	-
	17-20M	96.4	0.96	2.16	0.13	-
	20-23M	94.4	0.96	2.14	0.47	-

tourmaline (blue and rose-brown), zircon and magnetite.

PROVENANCE OF THE SAND

The diverse heavy mineral assemblages of the Musquodoboit, Diogenes Brook and Belmont sand suggest different source rocks for each of the deposits. It is also evident from the reworked palynomorphs in the Musquodoboit and Diogenes Brook deposits that the underlying Windsor Group provided, at least initially, a local source of sand. Stea and Fowler (1981) suggest a local source of detritus for the Brazil Lake deposit based upon the heavy mineral assemblage identified.

The Craignish and Strathlorne Formations of the Horton Group northeast of the Cretaceous sediments in the Musquodoboit Valley, may have provided an important source of detritus. Zircon and tourmaline have been described in the Horton Group sediments (MacDonald, 1974) as have ilmenite and staurolite (Clifton, 1963). The Meguma Group metasedimentary rocks may have provided the pyrite and magnetite. The high percentage of poikiloblastic, inclusion-riddled ilmenite is indicative of volcanic rocks of the Cobequid Highlands (Chatterjee, personal communication). This would indicate that a major drainage system was operating in middle Cretaceous time linking the Cobequids to the Musquodoboit Valley, most probably along the lines of modern drainage.

The heavy mineral assemblage from the Belmont deposit contains over 80% ilmenite which is probably derived from volcanic rocks of the Cobequid Highlands. Hence, the provenance of this deposit is more local than that of the Musquodoboit deposits.

The Diogenes Brook deposit consists of sand with a heavy mineral suite composed of magnetite, ilmenite and traces of garnet, amphibole, staurolite, tourmaline and zircon. The granitic rocks of the Creignish Hills could

provide the magnetite, garnet and amphihole, whereas the metasedimentary rocks of the George River Group could provide the staurolite. The angularity of the mineral grains suggests an immature sedimentation process and the heavy mineral assemblage suggests a local provenance.

PALEOGEOGRAPHIC HISTORY

INTRODUCTION

Oil and gas exploration has been on-going off Canada's east coast since the early 1970s and as a result a virtually complete stratigraphic record spanning the Jurassic to Pleistocene has been interpreted from the many drillholes spudded from the Grand Banks of Newfoundland to the Scotian Shelf. Accounts of the tectonic and depositional history of the east coast, as interpreted from the drillhole data, have been widely published in much detail (Jansa and Wade, 1975; Hart, 1976; King, 1972; Wade, 1981). However, due to the lack of information on the extent and nature of the Cretaceous deposits on land in Nova Scotia previous writers have been unable to explain their presence and their relationship to the offshore deposits.

This chapter will summarize the Scotian Shelf stratigraphy, correlate the terrestrial Cretaceous of Nova Scotia with its corresponding offshore counterpart and suggest possible paleogeographic and paleoclimatic conditions during the time of deposition and subsequent deep weathering of the central Nova Scotian and Cape Breton Island Cretaceous deposits.

STRATIGRAPHIC RELATIONSHIPS: SCOTIAN SHELF - MAINLAND NOVA SCOTIA

The oldest recognized outlier of terrigenous sediment of Cretaceous age in Nova Scotia occurs at Diogenes Brook, Cape Breton, and is Valanginian in age. Therefore, for purposes of this discussion, the Scotian Shelf stratigraphy will be discussed beginning with the Early Cretaceous through to the Pliocene. It is important to note that a few thousand metres of Jurassic sediments, not discussed here, make up the lower part of the sedimentary pile representing the total package of Scotian Shelf rocks.

During the Late Jurassic a change from shallow water marine sedimentation to continental clastic deposition was initiated in response to regional tectonic movements. These positive tectonic movements were related to the decoupling of the North American Plate from the Eurpoean Plate about a spreading centre located east of the Grand Banks (Jansa and Wade, 1975). In addition to regional uplift along the trailing edges of tectonic plates, local ridges and tilted blocks formed along the edges of rift valleys in a process referred to as ramping. Thus, a series of sub-basins formed along northwesterly trending basement highs which provided rejuvinated sediment source areas for actively subsiding Atlantic margin basins. The resulting deltaic system is represented by the Missisauga and Logan Canyon Formations (Fig. 7) which together attain a thickness of over 2.5 km.

The Missisauga Formation consists of over 1200 m of medium- to fine-grained sandstone in which the quartz grains are subangular to subrounded with silica overgrowths and kaolinite. The feldspar content is in the order of 5%. The Missisauga Formation thins rapidly eastward to less than 350 m at Sable Island where it is transitional to the more calcareous facies of the LaHave platform. This Formation represents a seaward prograding delta complex with a suite of associated depositional systems such as alluvial plain, lower delta plain and delta front. The silica sand deposit at Diogenes Brook, Cape Breton, may represent the landward extent of the Missisauga Formation as it is Valanginian in age and the more severe tectonic activity associated with the Avalon Uplift may have produced grabens and basins as far east as Cape Breton Island.

During the Aptian or early Albian a renewed pulse of ocean floor spreading initiated renewed tectonic uplift and ramping with associated sedimentation. In the Scotian Basin a regional transgression began which resulted in the deposition of the Logan Canyon Formation, which is up to 1200 m thick in the Sable Island area and thins eastward. It consists of a sandstone and shale sequence of which sand constitutes 25%. The sandstone is quartzose and moderately sorted, with sorting increasing upwards. Feldspathic beds are common with up to 25% orthoclase and microcline. The shale and siltstone are light- to greenish-grey in colour, glauconitic, and contain coalified plant fragments. The sediments were deposited on a deltaic coastal plain with distributary channels, bays and marshes. In the Sable Island area, sand bars and sand barriers enveloped by shaly deposits are present in the Logan Canyon delta front.

The clay and sand deposits of the Musquodoboit and Shubenacadie valleys were laid down contemporaneously with the Logan Canyon Formation as part of the deltaic system initiated by tectonic block faulting during Albian time. Sedimentation also continued in the Diogenes Brook area into the Albian and later. With continued transgression, the Dawson Canyon Formation shale and limestone and Wyandot Formation chalk beds were laid down in the Scotian Basin.

Coal compaction tests on Musquodoboit and Diogenes Brook samples indicate that over 750 m of sediment accumulated over what is now Nova Scotia (Hacquebard, 1984). This would imply that the northward limit of the Cretaceous transgression may be much greater than previously thought, perhaps extending into southern New Brunswick, as deposits of silica sand of probable Cretaceous age occur in the Sussex area (J. Fowler, personal communication).

During late Cretaceous or early Tertiary time rapid tilting of the shelf areas led to erosion and reworking of the near shore strata (Jansa and Wade, 1975). This tilting occurred about a hinge zone just north of Sable Island (Wade, 1981) and resulted in the erosion of sediments over what is now Nova Scotia and

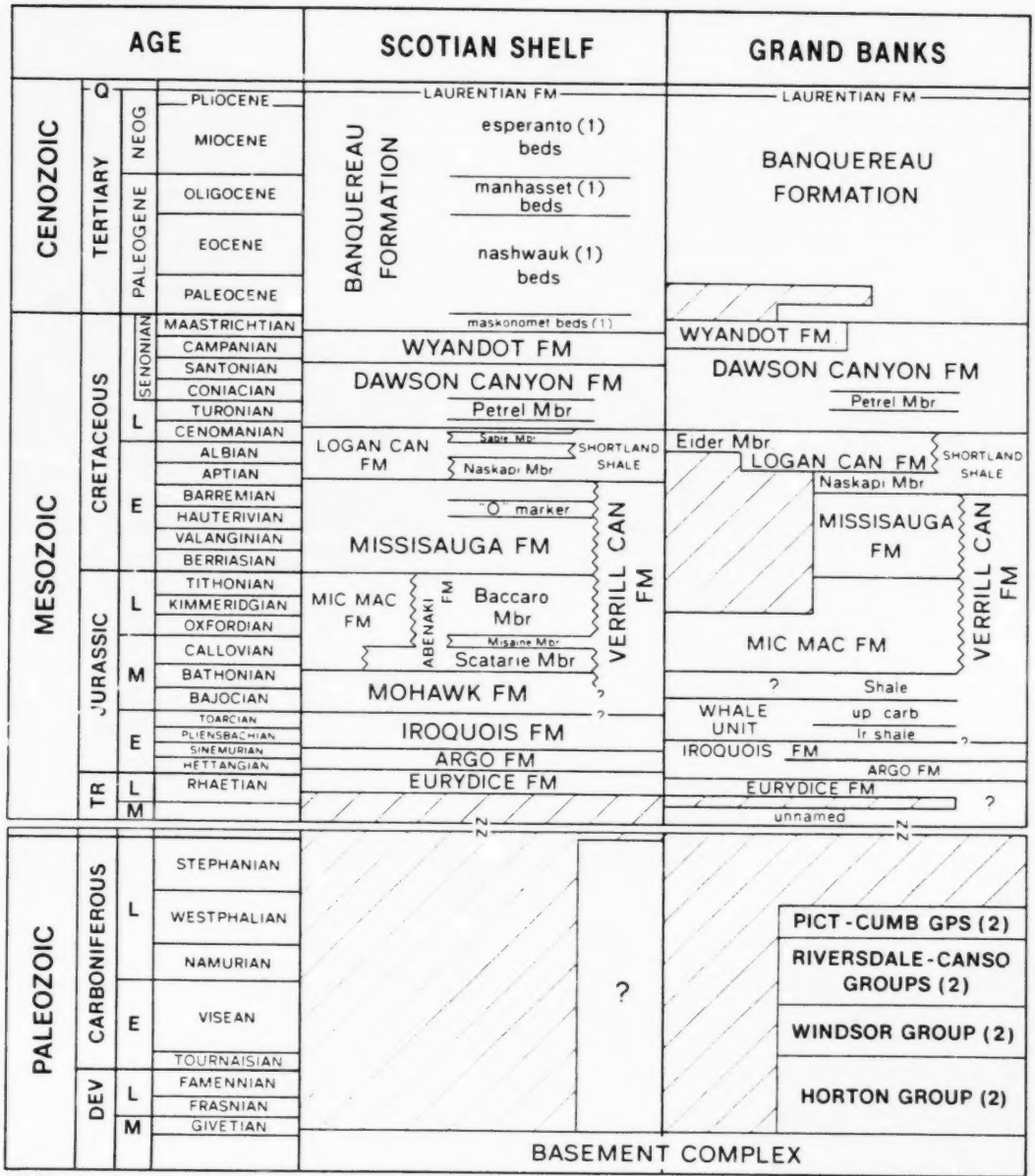

Figure 7. Generalized stratigraphic table for Scotian Shelf and Grand Banks (after Jansa and Wade, 1975).

Cape Breton Island and deposition of a prograding series of mudstones and sandstones of the Banquereau Formation. This formation is over 1200 m in thickness and was deposited during a major regression when sediment supply was much greater than the rate of basin subsidence. The regression culminated in the late Pliocene when glacial conditions prevailed across the emergent shelf.

POST DEPOSITIONAL WEATHERING

Very few pockets of Cretaceous sediment remain over Nova Scotia. The areas in which the largest deposits occur are fault-bounded basins, the bottoms of which are at least 100 m below present sea level. Other smaller deposits and occurrences are located in sink holes and depressions in Windsor Group rocks in several regions of Nova Scotia. The deposits are overlain by glacial debris, as are the offshore Cretaceous and Tertiary sediments. There is, however, a marked difference between onshore and offshore Cretaceous deposits.

The deposits of the Musquodoboit, Shubenacadie and Diogenes Brook valleys retain primary deltaic sedimentary features (Fowler and Stea, 1981), however, the sand beds are over 95% SiO_2 and the clay beds are virtually pure kaolinite. In contrast, the offshore sediments represent a more typical sedimentary sequence of feldspathic sandstone, mudstone and shale. It is clear that the onshore deposits have undergone a cycle of deep chemical weathering after their deposition. The weathering must have been initiated in the early Tertiary as the sediments north of the Sable Island hinge zone were uplifted and eroded to form the Banquereau Formation mudstones.

The process by which soils and sediments are weathered to silica and kaolinite has been studied and the various chemical reactions by which the process occurs have been demonstrated (Garrels and Christ, 1965). Most soils in areas of high rainfall and concomitant high leaching rates are kaolinitic and tend to have low pH values. The low pH results from a high CO_2 content in the soil atmosphere induced by the decomposition of organic material in the soils. Under some conditions the bacterial decomposition may be so rapid that the resulting CO_2 passes directly into the atmosphere leaving a soil so heavily leached that plant cover is sparse. In that case rainwater would pass directly through the soil relatively unbuffered, reducing feldspar to kaolinite and transporting the dissolved silica out of the system (Table 6).

The dissolved silica and potassium can be either carried out of the system by groundwater flow or some of the silica may be precipitated around quartz grains. In either case the destruction of K-feldspar is virtually complete if the process is maintained for long periods of time. In the case of the fine grained sediments or clays found in the Nova Scotia Cretaceous deposits, they may initally have been deposited as montmorillonite and kaolinite, then altered by deep weathering to produce pure kaolinite.

Table 6. Chemical reactions involved in the weathering of K-feldspar.

The reaction by which K-feldspar goes to kaolinite is as follows:

$2KAlSi_3O_8 + 2H^+aq + 9H_2O \rightarrow$
K-feldspar

$H_4Al_2Si_2O_9 + 2K^+aq + 4H_4SiO_4aq$
Kaolinite

Some of the K-feldspar can go to K-mica according to the following reaction:

$3KAlSi_3O_8 + 2H^+aq + 12H_2O \rightarrow$
K-feldspar

$KAl_3Si_3O_{10}(OH)_2 + 6H_4SiO_4aq + 2K^+aq$
K-Mica Dissolved Silica

The paleoclimate in the Nova Scotia area must have been warm and humid (Hart, 1976) with high rainfall causing the Cretaceous deposits to weather as they have. This climate may have persisted well into the Tertiary as the deposits were eroded and weathered to their present levels.

SUMMARY AND CONCLUSIONS

The Cretaceous deposits of Nova Scotia appear to be related to processes of sedimentation which occurred in the Scotian Basin as a result of tectonic uplift and ramping due to the initial stages in the development of the Atlantic Ocean basin. The sand deposit at Diogenes Brook, Cape Breton, is located in a fault-bounded basin and corresponds in age to the Missisauga Formation offshore. A later transgression in Albian time, coupled with ramping and tectonic activity in the central Scotian Basin, resulted in the deposition of the Logan Canyon Formation. The Musquodoboit and Shubenacadie sand and clay deposits accumulated at this time.

The marine transgression continued until the late Cretaceous with over 750 m of sediment accumulating over what is now Nova Scotia. Uplift and erosion of this sediment began in the early Tertiary along the Sable Island hinge zone resulting in deposition of the offshore Banquereau Formation mudstone and sandstone. During the early Tertiary climatic conditions were humid subtropical with high rainfall. This resulted in deep weathering of the exposed, unconsolidated sedimentary pile producing the silica sand and kaolinite deposits which occur in the Musquodoboit, Shubenacadie and Diogenes Brook areas.

This depositional model is important to the exploration geologist looking for these

deposits. Area selection will be based upon finding a fault-bounded basin with appropriate sediment supply and enough depth to allow preservation of the sediments from Tertiary erosion and Pleistocene glaciation.

It is impossible to determine the depth of a basin from surface observations alone. Refraction seismic profiles were useful in determining the depth of the Musquodoboit Basin Cretaceous deposits. It is also important to test the basin depth at various points because due to the nature of the block faulting and ramping process some parts of the basin may be downthrown deeper than others. In the case of the Musquodoboit Valley the depth to the Carboniferous erosion surface was over 190 m locally.

Once refraction seismic profiles outline a deep basin, diamond-drilling is necessary to test for Cretaceous deposits. Using the proper equipment it is possible to core the clay and recover sand samples from the drill collar. Several holes were completed in this manner for the purposes of this study. The Diogenes Brook deposit was drilled and sampled and initial indications suggest the deposit contains over seven million tonnes of silica sand grading over 95% SiO_2. Diamond-drilling in the Musquodoboit Valley has extended the known Cretaceous clay and sand deposits from Dickey Brook to Kent Brook.

Heavy mineral studies of the Musquodoboit sand suggest a provenance extending north to the Cobequid Highlands. The provenance of the Diogenes Brook sand was probably the Cape Breton Highlands.

As with other minerals, silica sand and clay are nonrenewable resources and new deposits must be found to replace those being consumed. It is hoped that this work will renew interest in exploring for silica sand and clay deposits in Nova Scotia. It provides information designed to guide exploration geologists into the most favourable areas and illustrates the tools by which deposits can be located and evaluated, both in size and quality.

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APPENDIX 1

SAMPLE SEISMIC PROFILE AND DEPTH CALCULATION

EXAMPLE OF CALCULATIONS

Examples of seismic records (Fig. 8) and data (Fig. 9) are presented in this Appendix.

The first step is to identify the various layers according to their velocities. Straight lines have been drawn through the arrival times (Fig. 9). The apparent velocities that result from this procedure would indicate a two-layer situation.

$$V_1 = 1754 \text{ m/s true velocity}$$

The dip angle is determined from the formula:

$$Y = \sin^{-1}\frac{V_1}{V_{2D}} - \sin^{-1}\frac{V_1}{V_{2U}}$$

$$Y = \sin^{-1}\frac{1754}{3846} - \sin^{-1}\frac{1754}{3846}$$

$$Y = 0 \text{ degrees}$$

To obtain the true value of V_2 the following formula is used:

$$V_2 = \frac{2\,V_{2U}\,V_{2D}}{V_{2U} + V_{2D}}\cos Y$$

$$V_2 = \frac{2\,(3946)(3846)}{(3946 + 3846)}\,(1)$$

$$V_2 = 3846 \text{ m/s true velocity}$$

Now that we have true velocities for V_1 and V_2, the layer thickness can be calculated under each shot point at each end of the seismic spread.

Side A

$$Z_1 = \frac{(Ti_2)V_1}{2\cos(\sin^{-1} V_1/V_2)}$$

$$Z_1 = \frac{(.045)\;\;1754}{2\cos\,(\sin^{-1} 1754/3846)}$$

$$Z_1 = \frac{78.93}{1.78}$$

$$Z_1 = 44 \text{ metres}$$

Similarly from Side B $Z_1 = 44$ metres

Where there is a region of overlap for refractions from the second layer, the delay-time method can be used to calculate additional depths to bedrock.

$$Z_D = \frac{\Delta T_D V_1}{\cos(\sin^{-1} V_1/V_2)}$$

Where $\Delta T_D = 1/2(T_{D1}+T_{D2}-T_t)$

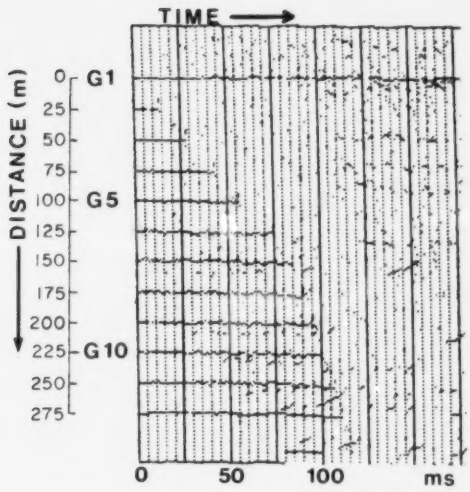
$\Delta T_D = 1/2(0.091s+0.147s-0.188s)$

$\Delta T_D = 0.025s$

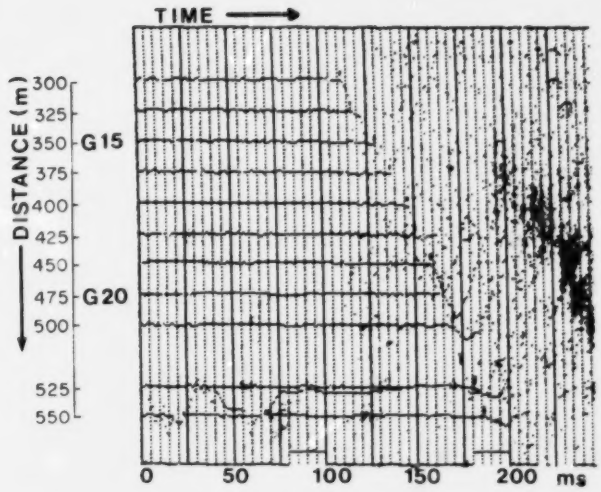
So, $Z_D = \frac{.025\ (1754)}{\cos(\sin^{-1} 1754/3846)}$

$Z_D = 49$ metres

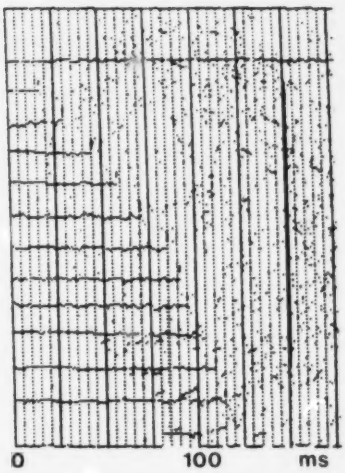
Other points can be computed in a similar manner, so that thicknesses of layers can be computed on a more detailed basis.



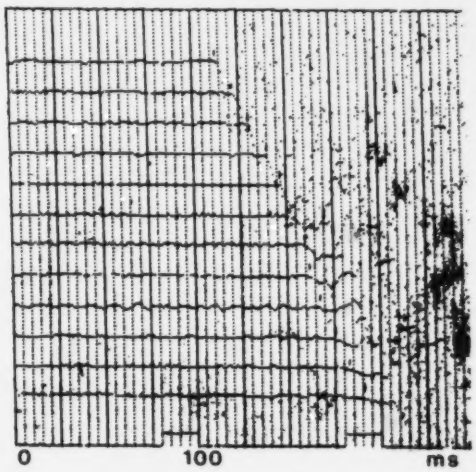
PROFILE # 21 FORWARD
0 + 00 to 2 + 75 SHOT AT 0 + 00
0.25 kg at 1.5 m



PROFILE # 21 FORWARD
2 + 75 to 5 + 50 SHOT AT 0 + 00
0.5 kg at 1.0 m



PROFILE # 21 REVERSE
5 + 50 to 2 + 75 SHOT AT 5 + 50
0.25 kg at 1.0 m



PROFILE # 21 REVERSE
2 + 75 to 0 + 00 SHOT AT 5 + 50
0.75 kg at 1.5 m

Figure 8. Example of seismic records from Musquodoboit Valley seismic refraction survey.

ARRIVAL TIME PICKS FROM PROFILES (MILLISECONDS)

	FORWARD	REVERSE
G1	0	0
2	14	17
3	28	30
4	44	45
5	56	58
6	75	70
7	85	85
8	90	91
9	95	95
10	100	100
11	107	110
12	111(112)	113 (113)
13	117	122
14	130	130
15	138	140
16	147	147
17	150	152
18	158	160
19	165	162
20	170	168
21	175	175
22	181	182
23	187	190

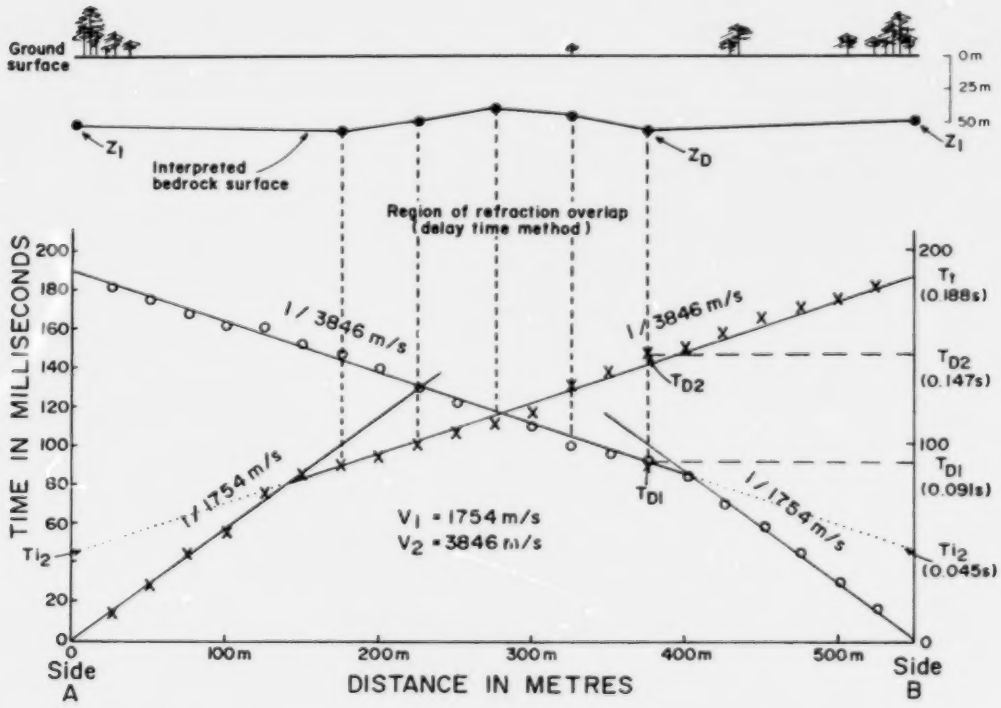


Figure 9. Example of data from Musquodoboit Valley seismic refraction survey.

APPENDIX 2

DIAMOND-DRILL HOLE LOGS AND SECTIONS

Figure 10. Diamond-drill hole sections. Depth in metres.

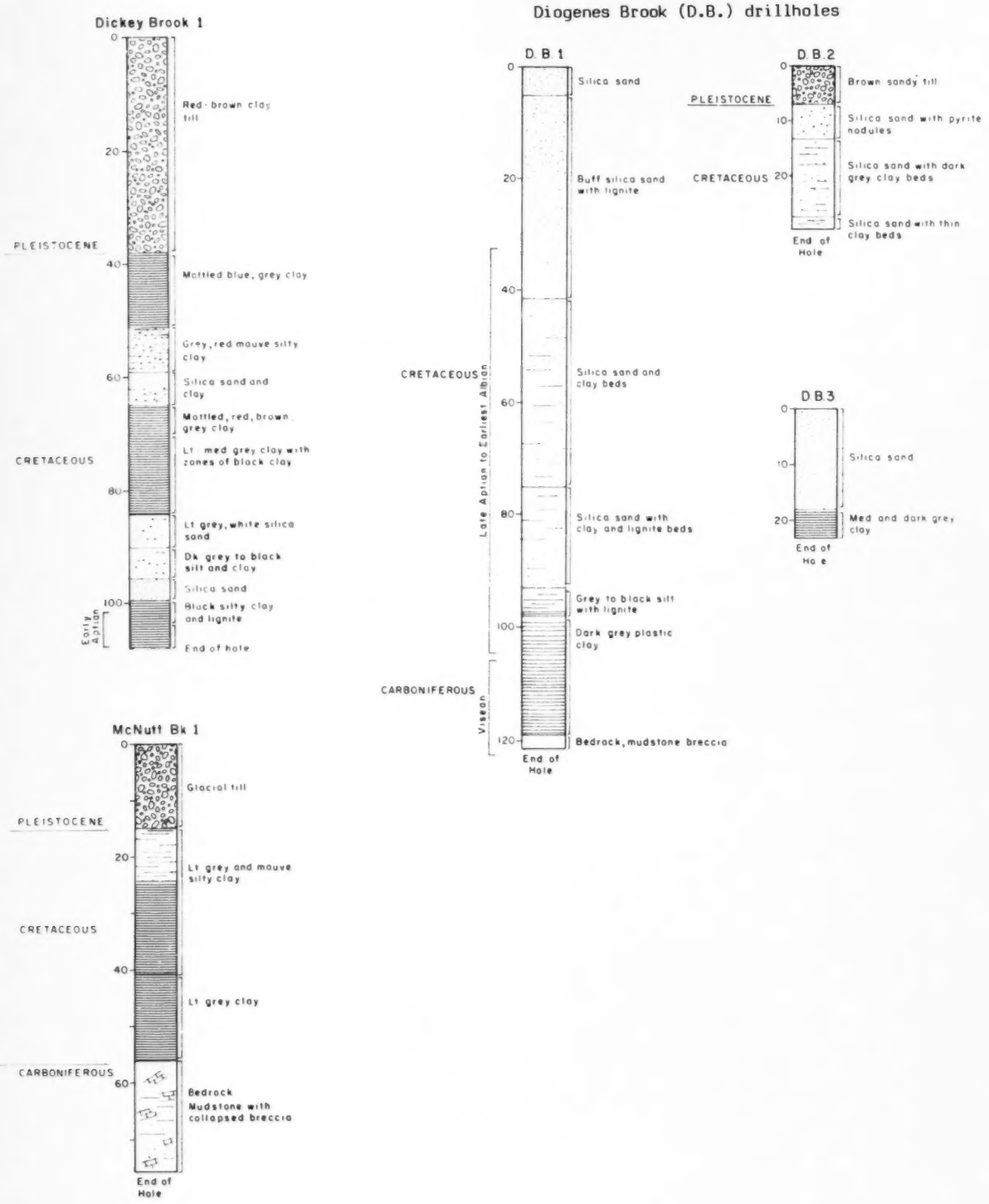


Figure 10. Diamond-drill hole sections (continued). Depth in metres.

NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY
DIAMOND-DRILL RECORD

Sheet 1 of 1

PROPERTY: **McNutt Brook** (McN-1) HOLE NO. 1

Latitude 45° 03' 21"	Departure 63° 10' 16"	Elevation	Section From: 0 To: 76 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0-15	Overburden					
15-18	Lt. grey & mauve clay					
18-24	Lt. grey silty clay					
24-41.6	Mauve & lt. grey clay					
41.6-42.0	Lt. grey silty clay					
42.0-42.5	Brownish grey massive clay					
42.5-43.2	Lt. grey compact clay					
43.2-43.3	Lt. grey medium sand with pyrite					
43.3-53	Lt. grey compact clay					
53-55	Dk. grey plastic clay, brown plastic clay					
55-56	Lt. grey massive clay					
56-56.5	Fault breccia ? Mudstone matrix with slate frags. & qtz.					
56.5-68.0	Lt. grey mudstone (Bedrock ?)					
68.0-73	Brecciated mudstone & mudstone					
73.0-76	Interbedded fine s.s. with muddy zones. Collapse					
	features. Mottled red & grey					
	END OF HOLE					

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PROPERTY: **Dickey Brook** (DB-1) HOLE NO. 1

Latitude 45° 04' 06"	Departure 63° 06' 20"	Elevation	Section From: 0 To: 55.6 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0-35.06	Red-brown clay till with numerous clasts of Halifax					
	slate & qtzite. Thin sandy beds near basal part of unit					
35.06-38.11	Lost core					
38.11-44.81	Massive mottled red (green-brown) clay. Plastic					
44.81-47.2	Greenish-brown silty clay - medium plastic					
47.2 -47.4	Blue-grey plastic clay with lignite					
47.4 -48.6	Brown-green silty clay - low plastic					
48.6 -50.31	Blue-grey to light grey medium plastic clay. Grades to					
	light grey at bottom					
50.31-51.2	Massive grey-brown clay -low plastic					
51.2 -51.7	Mottled light grey-red-lime green clay with red-brown					
	nodules or concretions avg. 3-5mm in diameter					
51.7 -53.36	Mottled grey-red massive clay. Zones of grey clay.					
	Zones of lime green stain					
53.36-53.6	Red-grey mottled clay with nodules					
53.6 -54.2	Massive light grey clay - low plastic					
54.2 -54.4	Weathered grey-red-brown-lime green clay					
54.4 -55.4	Weathered grey-red-brown-green clay					
55.4 -55.6	Weathered grey-red-brown-green silty clay					

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PROPERTY: **Dickey Brook** (DB-1) HOLE NO. 1

Latitude	Departure	Elevation	Section From: 55.6 To: 70.96 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
55.6 -56.1	Mauve-light grey silty clay					
56.1 -58.5	Weathered brown-red-grey silty clay					
58.5 -58.7	Weathered brown-light grey mottled clay					
58.7 -59.3	Light grey clay with pyrite nodules, rosetted					
59.3 -59.4	Pyrite cemented non-calcareous sand,sulphide content 60%					
59.4 -59.9	White calcareous cemented sandstone with pyrite blebs					
	becoming less abundant with depth					
59.9 -62.5	Lost core (probably sand)					
62.5 -65.56	Mottled brown red clay grading to light grey clay					
65.56-65.8	Plastic brown clay					
65.8 -67.6	Grey-red-brown silty clay. Finely banded light grey-					
	brown (red) zones. Banding variable 30°-5°					
	(May be chemical banding along bedding planes)					
67.6 -68.6	Mottled brown-mauve-light grey clay					
68.6 -69.1	Grey-red-brown mottled clay					
69.1 -69.6	Plastic mauve clay					
69.6 -70.4	Pinkish-brown mottled clay within grey-red banding					
70.4 -70.7	Massive light grey clay					
70.7 -70.96	Dark grey to black low plastic clay					

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PROPERTY: **Dickey Brook** (DB-1) HOLE NO. 1

Latitude	Departure	Elevation	Section From: 70.96 To: 103.23 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
70.96-73.06	Medium grey clay with dark grey zones and silty bands.					
	10 cm black plastic clay					
73.06-83.85	Alternating massive units of light and medium grey clay					
	with zones of black clay. Low to medium plastic					
83.85-86.89	Light grey silt and silty sand. Coarse down					
86.89-90.19	Fine white silica sand with white mica					
90.19-93.04	Alternating zones of mottled brown-green clay and black					
	clay					
93.04-96.13	Dark grey to black silt with much pyrite & plant frags.					
96.13-99.18	Lost core (probably sand with pyrite and gravel)					
99.18-103.23	Black silty clay with abundant lignite & plant frags.					

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PROPERTY: **McCabe** (McC-1) HOLE NO. 1

Latitude 45° 05' 07"	Departure 63° 04' 18"	Elevation	Section From: 6.10 To: 67.7 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
6.10-25.9	Brown clay till with qtzite bldrs. & slate frags.					
25.9 -28.86	Fine-medium white silica sand					
28.86-32.01	Light to medium grey silty clay					
32.01-38.16	Lost core (Probably sand with gravely beds) qtz. pebbles					
38.16-41.16	Light grey silty clay with sandy bands					
41.16-53.36	No core (probably sand)					
53.36-54.22	Mauve green clay					
54.22-56.40	Rust col. pyrite cemented medium sand with 10 cm grey					
	clay band at bottom					
56.40-59.35	Ochrous red silty clay. Locally thinly laminated. 25°					
59.35-61.5	Alt. greenish-yellow and white f-m sand and silt/clay					
	at bottom					
61.5- 61.7	Buff-brown silty-fine sand					
61.7 -62.07	Grey sand buff-white clay					
62.07-62.32	Ochrous red clay					
62.32-62.4	White fine sand					
62.4 -65.5	Ochrous red silty clay, laminated 30°					
65.5 -66.3	Weathered mottled, red-brown & grey-green clay					
66.3 -67.7	Red-brown to brick red & brown-grey mottled silty clay					

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PROPERTY: McCabe (McC-1)

HOLE NO. 1

Latitude	Departure	Elevation	Section From: 67.7 To: 97.37 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
67.7 -68.19	White medium sand and clay with pyrite					
68.19-69.7	Mottled red-grey & brick red silty clay					
69.7 -74.69	Light grey fine sand and silt, interbedded zones					
	10-20 cm thick					
74.69-74.79	Dark mauve clay					
74.79-74.94	Buff-yellow silty clay					
74.94-79.09	Light-medium grey silty clay - silt-fine sand. Pyrite					
	common in medium grey units. Banding 0°					
79.09-80.09	Weathered buff-yellow-mauve-pink silty clay with pyrite					
	band at bottom					
80.09-80.39	Buff-yellow fine sand					
80.39-83.94	No core					
83.94-86.88	Fine - coarse silica sand with clay balls, bottoms in					
	2 cm pyrite band					
86.88-92.93	Mottled red-grey-yellow clay, mottled brick red plastic					
	clay, ends in brick-red					
92.93-93.53	Grey-red-mauve-mottled-brick red clay					
93.59-97.27	Very plastic light grey clay, massive					
97.27-97.37	Very hard pyrite cemented sandstone					

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PROPERTY: McCabe (McC-1) HOLE NO. 1

Latitude	Departure	Elevation	Section From: 97.37 To: 117.72 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
97.37-97.57	Light grey plastic clay					
97.57-97.9	Light grey calcareous sandstone with pyrite					
97.9 -99.2	Light grey silty fine sand					
99.22-99.7	Medium grey silty sand with wood frags.					
99.7 -99.72	Pyrite band					
99.72-102.07	Blue grey plastic clay					
102.07-103.07	Medium grey silty clay with pyrite					
103.07-104.7	Red and grey spotty silty clay and silt					
104.7 -105.12	Greenish yellow silty clay					
105.12-106.07	Medium grey silty clay					
106.07-106.08	Pyrite					
106.08-106.58	Dark grey plastic clay					
106.58-108.23	Light-medium grey plastic clay					
108-23-111.28	Mottled medium grey-brick red medium plastic clay					
111.28-111.94	Greenish brown-mauve medium plastic clay					
111.94-113.54	Medium dark grey-brown clay					
113.54-114.09	Yellow-mauve-green massive clay					
114.09-117.07	Mottled red-grey-brick red mottled clay					
117.07-117.72	Mauve grey clay					

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PROPERTY: McCabe HOLE NO. 1

Latitude	Departure	Elevation	Section From: 117.72 To: 156.9 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
117.72-120.10	Grey-greenish grey mottled clay					
120.10-121.5	Brown-red clay					
121.5 -122.5	Greenish-brown clay					
122.5 -123.77	Mottled red and grey clay					
123.77-124.17	Mauve clay					
124.17-124.43	Light-medium grey banded clay					
124.43-125.43	Mottled red-grey-yellow clay					
125.43-128.42	Mauve and red clay to mottled red-brick red-green-					
	mauve-red clay					
128.42-128.47	Pyrite and grey s.s. bark					
128.47-128.87	Red-grey silty clay					
128.87-129.17	Light-medium grey calcareous s.s.					
129.17-131.27	Green-red to grey to brick red clay and silty clay					
131.27-137.47	Medium-dark grey clay. Mainly low plastic with some					
	plastic zones					
137.47-148.16	Medium-dark grey massive clay. Low plastic					
148.16-151.31	Black pyrite clay with lignite					
151.31-151.51	Medium grey clay					
151.51-156.9	Black clay with lignite and pyrite nodules					

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PROPERTY: **McCabe** (McC-1) HOLE NO. 1

Latitude	Departure	Elevation	Section From: 156.9 To: 182.70 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
156.9 -157.9	Medium grey plastic clay					
157.9 -157.92	Pyrite and lignite band					
157.92-158.92	Black clay with lignite					
158.92-159.81	Medium grey plastic clay - silty clay, pyrite band					
159.81-159.85	Pyrite band					
159.85-161.35	Dark grey - black clay, grey plastic clay					
161.35-169.21	Light green plastic clay, medium green silty clay, dark					
	grey pyrite and lignite clay. Pyrite band @ 166.16.					
	Lignite @ 164.6					
169.21-172.26	Medium-light grey silty clay					
172.26-175.3	No core					
175.31-177.70	Medium-light grey silty clay and plastic clay					
177.70-177.71	Pyrite band					
177.71-178.06	Fine light grey sand					
178.06-178.35	Light green plastic clay					
178.35-180.10	Green-grey green clay					
180.10-182.00	Mottled red & grey clay 25° @181.80					
182.00-182.70	Greenish brown clay					

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PROPERTY: **McCabe** (McC-1)

HOLE NO. 1

Latitude	Departure	Elevation	Section From: 182.70 To: 193.60 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
182.70-188.20	Massive dark grey to black clay					
188.20-188.90	Medium grey compact clay					
188.90-191.60	Finely laminated grey mudstone, calcareous along					
	fractures					
191.60-193.60	Brecciated limey mudstone with pyrite and chalcopyrite					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude 45° 05' 36"	Departure 63° 03' 09"	Elevation	Section From: 3.41 To: 12.09 m

Datum	Bearing	Dip Vertical	Started (date) March 9, 1982	Completed (date) March 24, 1982	Ultimate Depth 117.18m	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
3.41-4.03	Med. sand rust red in colour. Silica sand					
4.03-4.64	Buff red med. silica sand					
4.64-5.27	Buff red grey silica sand					
5.27-5.89	" " " " "					
5.89-6.51	" " " " "					
6.51-7.13	" " " " "					
7.13-7.75	" " " " "					
7.75-8.37	" " " " "					
8.37-8.99	" " " " "					
8.99-9.61	Med-coarse buff silica sand					
9.61-10.23	Med. buff silica sand					
10.23-10.85	" " " "					
10.85-11.47	" " " "					
11.47-12.09	Med-fine buff silica sand					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 12.09 To: 37.8 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
12.09-12.24	Buff med. gr. sand with lt. grey and red clay (bedding					
	to core axis 90)					
12.24-19.00	Finely lam. buff red-grey clay, plastic, no silt					
19.00-20.00	Massive rust clay, med. plast.					
20.00-21.00	Mottled blue grey to grey clay, med. plast.					
21.00-21.30	Grey to buff silty clay, med-low plast.					
21.30-23.78	Mixed blue grey to grey, brown, ochre clays with silty					
	beds 2-4 cm thick, med-high plast.					
23.78-25.78	Lost core					
25.78-31.22	(2 metres lost) Interlam. brn. and red clay with 2-3 cm					
	thick silt beds. Med to v. plast. with silt units low					
	plast.					
31.22-31.40	Brn. silty clay with lt. grey specs. Low plast.					
31.40-32.7	(1 metre lost) Buff, red, grey, brn., v. plast. clay.					
32.7-34.5	Massive grey silty clay. Low plast. Becomes mottled					
	with dk grey clay in lower part.					
34.5-35.5	Med. grey silt with black lignite rich bands. Wood and					
	plant frags. common. Flecs of musc. in silty beds.					
35.5-36.3	Lt. grey silty clay, massive, low plast.					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 36.3 To: 59.05 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
36.3-37.8	Grey to block plastic clay, carbonaceous					
37.8-39.37	Med. to lt. grey clay, med. plast., mottled block at					
	top, massive at bottom.					
39.37-39.57	Lt. grey micaceous silty bed.					
39.57-40.57	Med. to lt. grey med. plastic massive clay, more silty					
	down hole.					
40.57-40.77	Grey mottled clay with silty units. (micaceous).					
40.77-42.00	Med. grey micaceous clay, mottled with block organic					
	frags. at bottom. Med. plast.					
42.00-42.60	Dk. grey to block organic clay, med-high plast.					
42.60-45.14	Lt. grey med-high plast. clay with silty units. Small					
	amount white mica in silt.					
45.14-48.36	Brn. grey to med. grey mottled clay, med to low plast.					
48.36-48.89	Block organic rich clay, low plast.					
48.89-54.25	Dk. grey to block clay with plant frags. Gen low plast					
	massive units.					
54.25-57.30	Block massive clay with abund. plant frags. & wood chip					
	Med-low plast.					
57.30-59.05	Dk. grey clay. Few plant frags. Massive. med-low plast.					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 59.05 To: 85.50 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
59.05-64.17	Med. grey silty clay, med-low plast., mottled lighter					
	grey in areas.					
64.17-70.37	Dk. grey to black fine sand and silt. (3 bags)					
70.37-71.50	Black organic rich med. plast. clay. Abund. plant stems					
	and wood chips.					
71.50-73.00	Fine silt and clayey silt, med. to dk. grey, some plant					
	frags. no plast., becomes more clay rich at bottom					
73.00-73.25	Dk. grey massive clay, low plast.					
73.25-74.00	Med. grey massive clay, silty.					
74.00-77.50	Mixed med. and lt. grey silty clay and silt. Massive					
77.50-78.45	Block organic rich silty clay.					
78.45-79.38	Med. grey silty clay, med. plast. Fine sand mixed with					
	clay locally.					
79.38-81.00	Dk. grey silty clay, massive, med. plast.					
81.00-82.46	Lt. to med. grey silt unit containing fine to med.					
	silica sand grains.					
82.46-84.00	Block silty clay and clay with traces of plant frags.					
84.00-84.32	Med. to dk. grey silty clay & silt with few plant frags.					
84.32-85.50	Dk. grey to block silty clay with abund. plant frags.					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 85.50 To: 113.00 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
85.50-86.80	Med. to lt. grey silt and silty clay, massive, fine sand					
	beds @ 86.7m.					
86.80-86.90	Fine dk. grey sand. Low to med. silt content.					
86.90-88.50	Hard massive med. grey silty clay. Well compacted, low					
	plast.					
88.50-88.80	Olive to buff massive clay, low plast.					
88.80-90.83	Lt. grey v. fine sand and silt with few clay beds. Sand					
	has low to med. silt content.					
90.83-92.07	Lost core.					
92.07-96.10	Lt. to med. grey silt and v. fine sand. (bag).					
96.10-96.72	Mottled grey, red, brown clay, v. plast.					
96.72-98.00	Red-brown silty clay, massive, med. to low plast.					
98.00-98.27	Dk. grey and buff plastic clay.					
98.27-104.47	Dk. to med. grey massive clay and silty clay. Med. to					
	v. plastic. 98.2 to 99.0 organic rich.					
104.47-106.00	Med. grey massive silty clay.					
106.00-109.00	Med. grey mottled silty clay.					
109.00-110.00	Med. grey massive silt and silty clay.					
110.00-113.00	Med. grey plastic clay.					

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PROPERTY: **PAINT BROOK** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 113.00 To: 117.80 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
113.00-117.80	Finely laminated gypsum and limestone. Core angle to bedding 45°.					
	END OF HOLE					

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PROPERTY: **ELMSVALE** HOLE NO. 1

Latitude 45° 04' 47"	Departure 63° 03' 59"	Elevation	Section From: 0.00 To: 52.08 ft

Datum	Bearing	Dip Vertical	Started (date) March 25, 1985	Completed (date) April 1, 1985	Ultimate Depth 115.01m	Proposed Depth

Depth in Feet	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0.00-5.27	Red clay till with cobbles and pebbles.					
5.27-9.00	Lost core.					
9.00-9.30	Mottled buff, blue grey and red plastic clay.					
9.30-12.50	Mixed red, blue grey, grey plastic clay.					
12.50-14.20	Lt. grey silt.					
14.20-14.57	Fine lt. grey sand with high silica content.					
14.57-23.25	Mixed red and buff med. grained silica sand (11 bags)					
23.25-28.00	Mottled red, yellow grey, buff plastic clay.					
28.00-30.69	Mottled red med. plast. clay.					
30.69-31.31	Lt. grey silty low plast. clay.					
30.31-37.51	Buff lt. brown med. grey silica sand. (9 bags)					
37.51-39.00	Mixed lt. grey sand, lt. grey silty clay and lt. gr.silt					
39.00-42.16	Med. grey silt and silty clay.					
42.16-44.95	Brown to red fine silt and sand. (bag)					
44.95-48.05	Buff med. grained silica sand. (bag)					
48.05-48.67	Fine white silica sand (core)					
48.67-48.90	Black organic rich plastic clay.					
48.90-49.44	Med. to dk. grey clay. low plast					
49.44-52.08	Black organic rich, massive, low to med. plast. clay.					

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PROPERTY: **ELMSVALE** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 52.08 To: 88.00 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
52.08-52.39	Brown to med. grey sand (bag).					
52.39-52.70	Lost					
52.70-54.87	Fine brown silt (bag). Dark grey plastic clay (core).					
54.87-57.97	Med. grey silty clay, massive, low plast.					
57.97-59.21	Lost core.					
59.21-60.21	Med. grey to black med. plastic clay. Locally organic.					
60.21-64.17	Med. to fine silt beds, massive.					
64.17-68.51	Lt. brown med. to fine sand.					
68.51-70.37	Lt. grey to grey to white silt and clayey silt. Qtz.					
	pebbles 1 cm. in diameter @68.51 m.					
70.37-71.37	Lt. grey massive silt.					
71.37-73.00	Finely laminated clay and silt beds. Bedding to core					
	axis 20°.					
73.00-75.02	Drk. grey to black silty clay. Low-med. plast.					
75.02-75.95	Dk. to black organic rich plastic clay.					
75.95-79.05	Med. grey finely lam. silt and silty clay. Core angle					
	to bedding 90°.					
79.05-81.68	Med. grey massive med to low plast. clay.					
86.68-88.00	Intercalated mudstone, siltstone and limestone.					

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PROPERTY: **ELMSVALE** HOLE NO. 1

Latitude	Departure	Elevation	Section From: 88.00 To: 115.01 m

Datum	Bearing	Dip	Started (date)	Completed (date)	Ultimate Depth	Proposed Depth

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
88.00-91.45	Lt. grey mudstone. Thinly lam. Bedding to core axis 20°					
91.45-92.00	Med. grey thinly lam. mudstone.					
92.00-93.00	Med. to lt. grey siltstone and fine sandstone.					
93.00-95.17	Med. grey muddy fragmented mudstone.					
95.19-99.82	Brown, red and grey fragmented limestone and limy					
	mudstone.					
99.82-115.01	Interbedded marl, limestone and red limy mudstone and					
	fragmented limestone.					

NOVA SCOTIA DEPARTMENT OF MINES AND ENERGY
DIAMOND-DRILL RECORD

Sheet 1 of 1

PROPERTY: **Diogenes Brook** HOLE NO. D.B. - 1

Latitude 45° 00' 09"	Departure 61° 18' 18"	Elevation	Section From: 0 To: 121 m

Datum	Bearing	Dip -90	Started (date) October 21, 1982	Completed (date) October 29, 1982	Ultimate Depth 121 m	Proposed Depth 125 m

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0-5	Sand					
5-8	Buff fine sand with lignite					
8-41	Buff sand with lignite					
41-42	Lt. grey clay					
42-75	Silica sand with narrow clay beds					
75-93	Silica sand with narrow clay and lignite beds					
93-97	Grey and black silt & lignite beds; core to bedding 90°					
97-101	Dark grey plastic clay					
101-107	Dark grey plastic clay					
107-111	Dark grey plastic clay					
111-119.5	Dark grey clay & lignite beds (up to 3m thick)					
119-121	Bedrock (weathered breccia with sed. frags. in white					
	fine grain matrix)					

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DIAMOND-DRILL RECORD

Sheet 1 of 1

PROPERTY: **Diogenes Brook** HOLE NO. D.B. - 2

Latitude 45° 00' 08"	Departure 61° 18' 22"	Elevation	Section From: 0 To: 27 ft

Datum	Bearing --	Dip 90°	Started (date)	Completed (date)	Ultimate Depth 27 m	Proposed Depth 25 m

Depth in Feet	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0-7	Overburden sandy boulder till					
7-13	Silica sand with pyrite nodules					
13-27	Silica sand with dark grey clay beds					

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DIAMOND-DRILL RECORD

Sheet 1 of 1

PROPERTY: **Diogenes Brook**

HOLE NO. D.B. - 3

Latitude 45° 00' 08"	Departure 61° 18' 21"	Elevation	Section From: 0 To: 23 m

Datum	Bearing --	Dip 90°	Started (date)	Completed (date)	Ultimate Depth 23 m	Proposed Depth 25 m

Depth in Metres	FORMATION	Sample Number	Width of Sample	ASSAY VALUES		
0-18	Silica sand					
18-23	Medium and dark grey clay, core to bedding 70°					

MAPS
NOT
FILMED

CARTES
OMISES